NASA Procedures and Guidelines

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NASA SAFETY MANUAL PROCEDURES AND GUIDELINES

Responsible Office: QS/Safety and Risk Management Division

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PREFACE

P.1. PURPOSE

This NASA Safety Program Manual is the central Agency document containing procedures and guidelines that define the NASA Safety Program. This document serves as a general framework to structure the more specific and detailed requirements for Headquarters, Program, and Center Directors.

This is primarily a safety document and is not meant to provide direction to occupational health personnel or to provide guidance for occupational health activities. Some health references are included to assist Center safety personnel in interactions with the occupational health personnel primary occupational health and safety requirements are specified in NPG 8715.1, "Safety and Health Handbook-Occupational Safety and Health Programs."

This document is not a direct instruction to NASA contractors, but provides guidance to the responsible NASA contracting officer. It is applicable to contractors as appropriate through contract clauses in conformance with the NASA Federal Acquisition Regulation (FAR) Supplement. This document applies to the Jet Propulsion Laboratory (JPL) as directed by NPD 1410.3, "Application of the NASA Management Directives System to the Jet Propulsion Laboratory." Non-NASA, non-contractor personnel will follow the provisions of this document when on NASA property. This document shall not supersede more stringent requirements imposed by individual NASA organizations and other Federal, State, or local government agencies.

To address special processes and/or discipline unique processes, the NASA Headquarters Safety and Risk Management Division, publishes NASA Technical Standards (NTS) that are developed, prepared, periodically updated, and issued, to provide specific guidance instructions that are beyond the scope and detail of this document. A listing of active NTS documents can be found in paragraph P.4 References.

P.2. APPLICABILITY

The procedures and guidelines in this document apply: (1) to all NASA organizations, elements, entities, or individuals; (2) to all contractor personnel involved in operations at NASA facilities; (3) to all NASA equipment, property, systems, and facilities; (4) during all phases of the life cycle of systems or facilities, and (5) as required by contract requirements.

P.3. AUTHORITY

National Aeronautics and Space Act of 1958, as amended (42 U.S.C. 2471-2476).

Occupational Safety and Health Act of 1970 (PL 91-596).

Executive Order 12196 of February 26, 1980, “Occupational Safety and Health Programs for Federal Employees.”

29 CFR Part 1960, “Basic Program Elements for Federal Employees Occupational Safety and Health Programs and Related Matters.”

NHB 1101.3 “The NASA Organization, Chapter 4, 416, Office of Safety and Mission Assurance, Code Q.”

P.4. REFERENCES

NPD 8710.2, “NASA Safety and Health Program Policy.”

NPD 1800.2, “NASA Occupational Health Program Policy.”

NPD 1410.3, “Application of the NASA Management Directive System to the Jet Propulsion Laboratory.”

NPG 8715.1, “NASA Safety and Health Procedures and Guidelines – Occupational Safety and Health Programs.”

NPG 8715.x, “NASA Procedures and Guidelines for Pressure Vessels and Pressurized Systems.”

NASA-STD-8719.7, “NASA Facilities Safety Manual.”

NASA-STD-8719.8 “NASA ELV Payload Safety Review Process Manual.”

NASA-STD-8719.9 (will replace NSS 1740.9), “ NASA Lifting Devices and Equipment Manual.”

NASA-STD-8719.10 (will replace NSS 1740.10), “NASA Underwater Facilities Operations Manual.”

NASA-STD-8719.11 (will replace NSS-1740.11), “NASA Fire Protection Manual.”

NASA-STD-8719.12 (will replace NSS 1740.12), “NASA Explosives Safety Manual.”

NASA-STD-8719.13 (will replace NSS 1740.13), “NASA Software Safety Manual.”

NASA-STD-8719.14 (will replace NSS 1740.14), “NASA Orbital Debris Manual.”

NASA-STD-8719.15 (will replace NSS 1740 15), “NASA Oxygen and Oxygen Systems Manual.”

NASA-STD-8719.16 (will replace NSS 1740.16), "NASA Hydrogen and Hydrogen Systems Manual."

P.5. CANCELLATION

This document cancels NHB 1700.1(V1-B), dated June 1993.

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Associate Administrator
Office of Safety and Mission Assurance

CHAPTER 1: BASIC SAFETY MANAGEMENT

1.1 GENERAL

1.1.1. This document establishes the procedures and guidelines that define the NASA Safety Program. Safety compliance is a responsibility vested with senior management and executed by the immediate task supervisor and line organization. All employees are responsible for their own safety, as well as that of others whom their actions may affect.

1.1.2. In general, a safety program's success or failure can be measured by the number of incidents involving injury or death to personnel, loss of program capability, or loss of or damage to property. These incidents often result in personal tragedy, a loss of mission to the Agency, increased capital replacement costs, operational delays, lost productivity, short-and long-term financial costs to the Agency, medical expenses, or any combination of these. It must be recognized that NASA is involved in many activities with a high potential of risk. Risk evaluation, acceptance, tradeoffs are some of NASA’s most challenging activities and are an integral part of NASA's safety program.

1.2 BASIC POLICY

The policy for the NASA Safety Program is provided in NPD 8710.2, "NASA Safety and Health Program Policy." For specific health program requirements, see NPD 1800.1, "NASA Occupational Health Program."

1.3 OBJECTIVES

The objectives of NASA's Safety Program are to positively affect the overall success rate of missions and operations and to prevent injury to personnel and loss of or damage to property and/or technical reputation. Requisite program elements include:

1.3.1. An aggressive, centralized, and independent safety function for NASA to ensure that its programs/projects are accomplished safely.

1.3.2. Planning, direction, development of requirements, policies, methodology, procedures, implementation, and evaluation of the safety program to ensure its goals are achieved effectively and efficiently.

1.3.3. Up-to-date configuration control on equipment and systems.

1.3.4. Independent assessments of all systems prior to changes that might increase hazards to personnel or equipment.

1.3.5. Technical reviews of the safety aspects of all development efforts and operations to ensure that they are being conducted in accordance with sound safety engineering principles.

1.3.6. Investigation of all hazardous conditions, close calls, and mishaps, and prompt publication of lessons-learned as part of an accident-prevention, continuous improvement effort, without retribution to the employees.

1.3.7. Safety oversight/insight to ensure compliance with NASA safety policies and assess the effectiveness of NASA safety activities.

1.3.8. Safety research and development for new or unique safety functions and technologies to establish NASA as a national focal point for safety.

1.3.9. Compliance with the safety standards issued by the Occupational Safety and Health Administration (OSHA) in Section 6 of Public Law (PL) 91-596 (the Occupational Safety and Health Act). While these standards are used as the basis for the Safety Program, NASA has developed additional requirements to meet the challenges of mission environments. Unique NASA operations, materials, facilities, equipment, procedures, and practices may require establishment of alternate safety standards. If no standards apply, NASA will develop its own supplementary or alternate NASA safety standards for safety and mission assurance. (See NPD 8070.6 “Technical Standards” and NPG 8715.1 for further information on the policy for all NASA Technical Standards.)

1.3.10. Assessments of both qualitative and quantitative safety risks to program management along with recommendations to either reduce the risks or accept them. .

1.4. AUTHORITY AND RESPONSIBILITY

The NASA Administrator is the senior person responsible for Agency-wide safety. NASA Headquarters has established the Associate Administrator for Life and Microgravity Sciences and Applications as the NASA Designated Safety and Health Official (DASHO) pursuant to Executive Order 12196, Section 1-102, to serve as the coordinator of the Occupational Safety and Health Programs (reference NPD 8710.2B, “NASA Safety and Health Program Policy”). The authority and responsibility for safety policy and oversight are vested in the NASA Headquarters Safety and Risk Management Division within the Office of Safety and Mission Assurance (OSMA). Final authority and responsibility for safety at NASA facilities rest with the Center Directors. Each Center Director will designate a senior manager as the Center Safety and Health Official, who will be responsible for providing safety oversight activities, ensuring the safety of all Center operations/programs, and implementing the safety procedures and guidelines of this document.

1.5. PROGRAM ELEMENTS

Headquarters and Center Directors shall be responsible for ensuring that:

1.5.1. The safety organization is placed at a high enough level and a sufficiently senior person is designated to manage the effort so the safety review function can be conducted independently, the safety responsibilities of each organizational element are properly emphasized and accomplished, and adequate resources are available to support the safety efforts.

1.5.2. Centers establish executive safety and health committees or boards. NASA has exercised its option not to use the membership format established by OSHA for such committees as set forth in 29 CFR 1960, Subpart F, "Occupational Safety and Health Committees." The board will provide executive oversight, strategic planning, and program implementatio in support for the safety program.

1.5.3. Policies, plans, procedures, and standards that define the parameters of the safety program are established, documented, maintained, communicated, and implemented to provide for the appropriate or adequate protection and prevention of loss and damage to personnel, property, material, equipment, and facilities of NASA, other agencies, and the public. The Annual Operating Agreements enacted and signed by each Center reflect the agreed support activity level of the Center Safety Organization to the program/projects and institutional operations at the Centers.

1.5.4. Contractor operations and designs are reviewed and evaluated for compliance with the safety provisions of the contract and good safety practices. These results are provided to the award fee boards, where applicable. NASA safety personnel are included as regular participants in the procurement process for the acquisition of hardware, software, services, materials, and equipment. (See Chapter 2.)

1.5.5. An effective systems safety and mission asurance program is established to include development, review, and approval of project planning documents and the development and use of a risk assessment/hazard control system. (See Chapter 3.)

1.5.6. Qualified personnel and appropriate training are provided to support the safe performance of potentially hazardous or critical technical operations and to ensure a qualified safety workforce is available to support the safety assurance function. (See Chapter 4.)

1.5.7. An independent interagency review and approval process is implemented for the use of radioactive materials in spacecraft and the Space Transportation System to avoid unacceptable radiation exposure for normal or abnormal conditions, including launch aborts with uncontrolled return to Earth. (See Chapter 5.)

1.5.8. All NASA operations are performed in accordance with existing safety standards and consensus standards, or special supplemental standards when there are no known applicable standards. For hazardous operations, special procedures are developed to provide for a safe work environment. (See Chapter 6.)

1.5.9. Aviation Safety Programs tailored to meet the specific operational needs of the NASA Centers are established and maintained to comply with national standards, and NASA directives and guidance (See Chapter 7.)

1.5.10. All facilities are designed, constructed, and operated to comply with applicable/approved codes, standards, and procedures. (See Chapters 8 and 9.)

1.5.11. All accidents, incidents, mission or test failures, or other mishaps are promptly investigated for root cause. Continuous improvement is initiated through corrective actions and lessons learned, as specified in, NPD 8621.1, "NASA Mishap Reporting and Investigating Policy," and NPG 8621.x, "Procedures and Guidelines for Mishap Reporting, Investigating, and Recordkeeping."

1.6. RISK ASSESSMENT

The primary purpose of risk assessment is to identify and evaluate risks to support decision making regarding actions to ensure safety and mission success. The safety organization must assess the safety risks or hazards associated with current or planned activities. The decision (based on all relevant factors) to accept a hazard with its associated risk is a management responsibility and will require coordination and concurrence by the cognizant safety official and the Program Manager. In all cases, when a decision is made to accept a hazard with its associated risk, the next higher management level will be briefed on the decision. The probability of a mishap coupled with the severity of the possible consequences should be a major consideration in that decision. This is discussed in detail in Paragraph 3.5.

Risk assessment analysis should use the simplest methods that adequately characterize the probability and severity of undesired events. Qualitative methods that characterize hazards and failure modes should be used first. Quantitative methods should be used when qualitative methods do not provide an adequate understanding of failure causes, probability of undesired events, or the consequences of hazards or potential failures.

1.7. CONTROL OF HAZARDOUS CONDITIONS

Systems shall be designed to preclude the occurrence of a hazard or to negate or reduce the effect of a hazard that cannot be eliminated. (See Chapter 3 for Hazard Reduction Priority.) The level of protection required is a function of the hazard severity and may be achieved by a combination of availability, reliability, maintainability (restorability), and redundancy. The same level of protection against operator error is required.

1.7.1. Failure Tolerance - Safety critical operations that control or are applied to a condition, event, signal, process or item of which proper recognition, control, performance, or tolerance is essential to safe system operation, use, or function, shall be designed such that the operation of the function is assured. Design for failure tolerance is driven by system probability of failure requirements and the incorporation of the proper levels of redundancy. Where there is sufficient time lapse between a potential failure and manifestation of its effect, design for restoration or maintenance may be used as an alternative means of achieving failure tolerance. Where there is not sufficient time for recovery, redundancy must be provided.

1.7.1.1. Probability of failure to provide the function and an estimated time to restore the function shall be used to develop and assess the safety attributes of the design. The probability of failure shall be demonstrated to a lower confidence level of 95 percent in concert with a demonstrated mean time to restore (where appropriate) not greater than 50 percent of the estimated time to effect. The time-to-restore estimate shall include the combination of the active time to repair and the logistics or administrative downtime that affects the ease or rapidity of achieving full restoration of the failed function.

1.7.1.2. Use of redundancy to achieve failure tolerance requires specification of acceptable reliability and sufficient redundancy to tolerate two failures or operator errors where loss of life or mission critical event could occur and one failure or operator error where system loss/damage or personal injury could occur. Use of redundancy shall include a verifiable requirement that common cause failures (e.g., contamination) do not invalidate the failure tolerance. All redundancy in safety critical functions shall be verified under operational conditions.

1.7.2. Inhibits - Safety critical operations that require control of a condition, event, signal, process, or item of which proper recognition, performance or tolerance is essential to safe system operation, use, or function, shall be designed such that it cannot be enabled in an inadvertent or unauthorized manner. Safety critical operations shall require three inhibits where loss of life or mission-critical events could occur, and two inhibits where personal injury or system loss or damage could occur. All inhibits or procedures in safety critical operations shall be verified under operational conditions.

1.7.3. Loss of functional protection shall require termination of the operation at the first stable configuration.

1.7.3.1. For manned systems, safe haven, rescue, and escape can be valid means of life protection, and if used, shall include testing for validation, training, and demonstration.

1.7.3.2. A single level of protection is required to protect hardware. For high-value systems (high visibility), the program shall consider additional protection against loss and shall document the associated decision(s) and rationale.

1.8. NOTICE AND ABATEMENT OF UNSAFE OR UNHEALTHFUL CONDITIONS

The receipt of information concerning unsafe conditions, whether received through a report from an employee and verified, or as a result of a workplace inspection, will require the issuance of a Notice of Unsafe or Unhealthful Condition (NF 1390) and a NASA

Safety and Health Hazard Abatement Form (NF 1584) or equivalent forms. See Appendix B for sample forms. Imminent danger issues will be addressed in accordance with 29 CFR 1960.26. See NPG 8715.1, "NASA Safety and Health Procedures and Guidelines – Occupational Safety and Health Programs," for more information.

1.8.1. Inspection requirements vary according to the type of unsafe or unhealthful conditions that are reported.

1.8.1.1. An allegation of an imminent danger condition will require an inspection within 24 hours.

1.8.1.2. An allegation of a potentially serious condition requires an inspection within three working days.

1.8.1.3. Any allegation of other than imminent or serious safety or health conditions shall be inspected within 10 working days.

1.8.1.4. Further inspections may not be necessary if the hazardous condition(s) can be abated immediately through normal management action and prompt notification to employees and safety and health committees.

1.8.2. Written reports/notices of safety violations shall be issued not later than 15 working days after completion of the inspection and confirmation by the inspection official. Written reports/notices for health violations shall be issued not later 30 working days after completion of the inspection and confirmation by the inspection official.

1.8.2.1. A copy of the notice shall be sent to the official in charge of the workplace, the representative of the employees, and the safety and health committee.

1.8.2.2. Upon receipt of any notice of an unsafe or unhealthful working condition, the official in charge of a workplace shall immediately post such notice at or near each place where the condition exists or existed.

1.8.2.3. Each notice shall remain posted until the unsafe or unhealthful working condition has been abated or for three (3) working days, whichever is later.

1.8.3. An Abatement Plan (NF 1584 or equivalent) must be developed for hazards that cannot be abated within 30 days. A copy shall be provided to the safety and health committee, employee representatives, and the NASA Safety and Risk Management Division if Headquarters advocacy is required to secure funding.

1.9. SAFETY PROGRAM REVIEWS

1.9.1. General.

In addition to normal management surveillance, formal evaluation of the safety program shall be accomplished at least annually by competent and qualified safety personnel through safety surveys, safety evaluations, and in-depth safety inspections. A formal program for the abatement of hazards shall be in place. While review of accident reports, statistics, and program documents provide a general indicator of the extent and success of the safety program, objective evaluation visits by the functional safety management officials are required to enhance accident prevention efforts and to strengthen the effectiveness of the safety programs. The formal evaluation may be performed by the Center's safety staff or an independent outside source. These evaluations shall have specific objectives:

1.9.1.1. Evaluate the effectiveness of safety program management.

1.9.1.2. Identify hazards and suggest corrective action.

1.9.1.3. Determine the adequacy of safety standards and procedures.

1.9.1.4. Observe compliance with safety practices.

1.9.1.5. Assess compliance with measures taken to correct problems noted during any previous Process Verification visits/inspections/surveys.

1.9.2. Review Categories.

To determine the degree of formality attached to a safety visit process review, the following three specific types are designated:

1.9.2.1. Safety Staff Assistance Visits are informal on-site evaluations by specialists and safety personnel who, after making spot checks and/or sampling visits and holding discussions with appropriate levels of management, provide an assessment to the affected organization.

1.9.2.2. Safety Inspections are in-depth, technical reviews conducted at the working or facility level to assess the compliance with safety policies and standards that apply to the particular workplace. Formal reports of inspections shall be provided to the appropriate management level that is responsible for correcting the violations.

1.9.2.3. Process Verification examinations are documented management-level reviews performed in accordance with pre-approved subject areas outlines to verify by examination and evaluation of objective evidence, whether required safety program elements are in place and functioning. A written report is usually provided, and a written response containing a corrective action plan with milestone dates is usually not required.

1.10. ADVISORY PANELS, COMMITTEES, AND BOARDS

1.10.1 General.

It is NASA's intent that maximum use be made of the Nation's most competent safety resources. In keeping with this philosophy, NASA may enlist consultants, interagency and interdisciplinary panels, and ad hoc committees, consisting of representatives from industry (management and union), universities, and government (management and union), may be used to review and advise on the needs of the NASA Safety Program.

1.10.2. Aerospace Safety Advisory Panel (ASAP).

This Panel was established by Public Law 90-67 to serve as a senior advisory body to the NASA Administrator. The panel reviews safety studies and operations plans referred to it, prepares reports, and advises the Administrator with respect to the hazards to proposed or existing facilities and operations. See NPC 1156.14, "Aerospace Safety Advisory Panel," for further details.

1.10.3. Operations and Engineering Board (OEB).

This internal NASA board reports to the Associate Administrator for the Office of Safety and Mission Assurance (AA for OSMA). The Board supports the AA for OSMA on special assignments related to facilities operations and engineering activities. The OEB evaluates processes and systems for assuring the continuing operational integrity of NASA test facilities, operations and engineering technical support systems, and problems and issues at Centers, and provides recommendations to management in these areas. The OEB also studies technical support systems problem areas and develops alternate solutions or methods for arriving at a solution. See NPC 8701.X, “Operations and Engineering Board Charter,” for further details.

1.10.4. Interagency Nuclear Safety Review Panel (INSRP).

The INSRP provides an independent evaluation of the radiological risks associated with the launch of a nuclear power system. The Panel members, or coordinators, representing the Department of Energy (DOE), Department of Defense (DOD), and NASA, are independent of the program under review. These coordinators are empowered by their agencies to obtain facility and personnel support from within their agencies to provide the necessary expertise to support INSRP in its nuclear safety evaluation. Besides the Panel coordinators, representatives from the Nuclear Regulatory Commission, Environmental Protection Agency (EPA), and National Oceanic and Atmospheric Administration (NOAA) also participate in the radiological risk assessment. For further information on INSRP, see Chapter 5.

1.10.5. International Space Station Independent Assessment Panel (ISSIAP)

The ISSIAP provides an independent assessment function for the Associate Administrator Office for Safety and Mission Assurance that encompasses the products and activities of all program participants throughout the entire life cycle of the International Space Station (ISS) Program. The ISSIAP, to the maximum extent practicable, provides timely identification of program deficiencies and unacceptable risks, and makes recommendations concerning risk acceptability. The activities of the ISSIAP are complementary to the in-line safety, reliability, and quality assurance activities of the ISS Program.

1.10.6. System Safety and Risk Management Advisory Committee (SSARMAC).

This committee, established by the Director, NASA Safety and Risk Management Division, is chartered to (1) enhance the development, review, and reengineering of system safety and risk management policies; (2) facilitate the identification and prioritization of system safety research and technology activities; (3) foster the exchange of system safety and risk management experiences and successes within NASA; and (4) serve as a forum for discussion of issues. One member or members (if separate system safety and risk management representatives are needed) will be appointed from each Center and JPL.

1.10.7. System Safety Review Panel (SSRP).

The SSRP is a mechanism for enhancing the Space Shuttle Program (SSP) system safety management and engineering through informational interchanges, development of concepts to improve the Space Transportation System (STS) safety program, review of safety documentation, review of SSP integration and cargo integration, review of SSP element-level hazard identification and resolution activities, and recommendations to Level II management for hazard report disposition. See JSC NSTSPM Directive No. 110, "Space Shuttle Program (SSP) System Safety Review Panel (SSRP) Charter," for further details.

1.10.8. HEDS Assurance Board (HAB).

This board was created pursuant to the “Safety and Mission Assurance for the Human Exploration and Development of Space (HEDS) Enterprise” plan, dated April 3, 1996. Its purpose is to provide senior NASA management with timely, objective, non-advocacy assessments of program health and status, and the relative safety posture of the HEDS Enterprise. It is to remain in place only during the HEDS management transition taking place in the latter half of the 1990s. The HAB (1) assesses the work processes of the SMA community, (2) reviews HEDS programs to ensure that proper attention is being paid to risk, and (3) reviews the overall effectiveness of the hardware, software, and operational aspects of HEDS programs to assure safety and mission integrity. The HAB places special emphasis on the transition to the Space Flight Operations Contract and from NASA “oversight” to “insight.” The Board is chaired by the AA, OSMA, and includes the

SMA directors from JSC, KSC, and MSFC; the Chair of the Space Flight Safety Panel; the HEDS Independent Assessment Director; and the SMA managers for the Space Shuttle Program and the International Space Station programs.

1.10.9. Space Flight Safety Panel.

This Panel was established to promote flight safety in NASA space flight programs involving flight crews and to advise appropriate Associate Administrators on all aspects of the manned space program that affect flight safety. See NPC 1152.66C, "NASA Space Flight Safety Panel," for further details.

1.10.10. Problem Assessment Review - Payloads (PAR-P) Panel.

This PAR-P is composed of the Safety Directors from appropriate Centers and the Safety and Risk Management Division. The PAR-P will provide findings and recommendations to the AA for OSMA. Each space flight payload program will undergo an independent assessment of the effectiveness of its safety assurance process. The assessment uses information gathered from the normal safety review process and supplemented by information presented at the OSMA, PAR-P. This review and assessment will normally be completed after the final project and vehicle reviews and concurrent with the Office of Space Flight (or equivalent) Flight Readiness Review.

1.10.11. Pre-launch Assessment Review Panel (PAR)

The PAR process is a series of incremental OSMA reviews held for each Space Shuttle Mission and presented to senior SMA management. During this process appropriate assessments are presented by program SMA personnel to certify that the SR&QA/S&MA organizations have satisfactorily fulfilled the requirement to perform in-line assurance oversight and independent assessments of changes in risks associated with Space Shuttle hardware, software, processes and operations. These assessments are performed to verify that the program properly addresses safety and mission assurance. The incremental PAR reviews and the readiness statements signed at the completion of the reviews relate directly to the presentation subject matter. The Certification of Flight Readiness endorsements by SMA organizations and AA/OSMA, are based on results of the assessments made in support of the PAR process and the developed rationale for flight.

1.10.12. Ad Hoc Committees.

Center Directors may establish ad hoc committees to provide safety oversight review of programs, projects, and other activities under their purview.

1.11. PUBLIC SAFETY

1.11.1. NASA will strive to provide protection to the public from any adverse effects of NASA operations. Center Directors, Program/Project Managers, and line supervisors at all levels are responsible for ensuring that the public is not exposed to undue hazards as a result of NASA operations. If protection can be afforded through exclusion, adequate security measures will be imposed to limit public access and exposure. If protection must be afforded by safety restriction, adequate precautions and controls will be implemented based on the hazards identified by analysis. Where the possible hazardous effects of NASA operations extend past the Center boundary, agreements may also be needed to control public access to the affected area. NASA Safety and emergency planning officials should establish cooperative programs with the local community including:

1.11.1.1. Ensuring community awareness of the nature and extent of actual and potential hazards arising from the NASA operations and the measures being taken to protect the community.

1.11.1.2. Developing joint disaster evacuation plans to include radiological contamination, explosive/propellant mishaps, toxic chemical spills, tornadoes, hurricanes, floods, etc.

1.11.1.3. Participating jointly in community safety activities.

1.11.2. Occasionally, research personnel who are neither contractors nor visitors are allowed access to NASA facilities to conduct individual research under grants or other auspices. These research operations must not interfere with or damage NASA facilities or operations. If their work involves exposure to hazardous operations, the Center safety office shall require them to follow all NASA precautions and to procure protective clothing and equipment at their own expense, if needed. Also, if these personnel will be operating or using potentially hazardous NASA equipment, they must receive training and be certified as a qualified operator in accordance with Chapter 4 of this document.

1.12. COORDINATION WITH ORGANIZATIONS EXTERNAL TO NASA

1.12.1. The Office of Safety and Mission Assurance (OSMA), in close coordination with the Office of Policy Coordination and International Relations, shall establish guidelines for exchanging safety information with other government agencies, private agencies, and foreign governments (e.g., Underwriters/Laboratories, Defense Logistics Agency (DLA), EPA, and space agencies of other space-faring nations). New and different methods and practices that may be beneficial to NASA should be brought to the attention of the responsible Headquarters office.

1.12.2. Active participation by NASA safety professionals and other NASA officials in outside job-related activities is encouraged. Examples are functions and committees of the National Safety Council, National Fire Protection Association, DOD Explosive Safety Board, National Academy of Sciences, System Safety Society, American Society of Safety Engineers, Field Federal Safety and Health councils, and the Joint Army, Navy, NASA, Air Force (JANNAF) propulsion committee.

1.13. MATERIAL SAFETY DATA SHEETS

All NASA procurement activities require the referencing of 29 CFR 1910.1200 and Federal Standard 313, "Federal Standard for Preparation and Submission of Material Safety Data Sheets" (MSDS's), as revised, in commodity specifications, purchase descriptions, purchase orders, contracts, and other purchase documents. The receiving office at each Center shall provide copies of the MSDS's for receipt of such commodities to the central office responsible for maintaining the MSDS records. Magnetic disk or paper copies of all MSDS's will be maintained in the work area where the material is being used or stored. See NHS/IH-1845.3, "Hazard Communication."

1.14. EMERGENCY PLANNING

1.14.1. The NASA Emergency Preparedness Plan is NASA’s part of the Government program to maintain critical government functions during national emergencies rangeing in severity from fires and civil riots to a full-scale military attack on the United States. Emergency plans shall be in place, discussed with the appropriate personnel, and exercised periodically for all NASA activities so that reaction to emergency situations is rapid and effective. Such plans will cover national emergencies and disasters, mishaps, and the communication of information.

1.14.2. NPD 8710.1, "Emergency Preparedness Program Policy," and NPG 8715.x, "NASA Emergency Preparedness Plan" establishes NASA policy, requirements, and procedures in this regard. Center Directors are responsible for preparing their organizations to handle emergencies and disasters effectively and for developing the Center emergency plan. The guidance for developing this plan is furnished by the General Services Administration (GSA) in 41 CFR 101 and 29 CFR 1910.

1.15. SAFETY MOTIVATION AND AWARDS PROGRAM

This program recognizes notable safety-related contributions to NASA programs and operations. (See Appendix C) The following paragraphs establish general policy and responsibilities and identify the primary types of safety performance to be recognized:

1.15.1. NASA is committed to continued improvement of safety in all operational phases. NASA's policy is to stimulate the participation of employees in this effort. The presentation of awards is considered appropriate for recognizing outstanding safety-related performance/contributions and is an effective means of encouraging safety excellence.

1.15.2. NASA recognizes responsible individuals and organizations for:

1.15.2.1. Taking significant safety initiatives.

1.15.2.2. Making truly innovative safety suggestions.

1.15.2.3. Meeting major safety goals.

1.15.2.4. Making significant achievements leading to the safer and more effective use of resources or execution of NASA operations.

1.15.2.5 Encouraging and rewarding safety excellence among employees (applies to supervisors).

1.15.3. NASA safety awards shall recognize the safety achievements of NASA and other Federal Government employees supporting NASA objectives in all occupational categories and grade levels. Employees of the Jet Propulsion Laboratory (who are performing NASA work) shall be treated as Federal Government employees for safety awards. NASA safety awards programs also may provide for the recognition of non-Federal personnel supporting NASA objectives.

1.15.4. The Space Flight Awareness Program for NASA and the supporting contractors, promotes safety, particularly for crewed flight. The goal of this program is to instill in employees the need to reduce human efforts and mistakes that could lead to space flight mishaps and mission failure.

1.16. SAFETY MANAGEMENT INFORMATION

Efficient communication of safety information is necessary to meet the needs of safety officials and the managers they support. This includes communications between and among operational and safety organizations. NASA safety organizations will pursue every practical means for communicating verbal and written safety management information, lessons learned, and statistics. Examples of NASA information systems are the Incident Reporting Information System (IRIS) and the Lessons Learned Information System (LLIS).

1.16.1. Recordkeeping and Reporting Requirements.

Records and reports of accidents, occupational injuries, incidents, failure analyses, identified hazards, mishaps, appraisals, and like items, contain information necessary for developing corrective measures and lessons learned. NASA shall maintain detailed records of occupational injuries that are reported to OSHA in accordance with 29 CFR 1960, Subpart I, "Recordkeeping and Reporting Requirements." Detailed information is provided in NPD 3810.1, "Processing claims Under the Federal Employees Compensation Act."

1.16.1.1. Employees are allowed access to these data and their medical exposure records in accordance with Federal regulations (29 CFR 1910).

1.16.1.2. NASA Headquarters requires Centers to maintain records and report occupational injuries and illnesses as specified in NPG 8621.x, “NASA Procedures and Guidelines for Mishap Reporting, Investigating, and Recordkeeping.”

1.16.1.3. NASA also publishes a periodic Safety Program Status Report for internal Agency use.

1.16.1.4. Mishap Reporting, Investigation, and Recordkeeping requirements are addressed in NPD 8621.1G and NPG 8621.xx.

1.16.2. Furnishing of Documents to NASA Headquarters.

The following documents shall be forwarded to the NASA Safety and Risk Management Division Director:

1.16.2.1. Center executive safety board documentation (e.g., minutes and reports).

1.16.2.2. Results of external (such as OSHA) safety program management reviews.

1.16.2.3. Top-level Center or program safety policy documents that implement Headquarters requirements. Electronic versions are acceptable.

1.16.2.4. Major mishap reports as required by NPD 8621.1G “NASA Mishap Reporting and Investigating Policy,” and information as requested by Headquarters in NPG 8621.xx “NASA Procedures and Guidelines for Mishap Reporting, Investigating, and Recordkeeping”

1.16.2.5. Copies of comments sent to outside regulatory agencies (e.g., OSHA, Department of Transportation (DOT), EPA) concerning proposed rule-making that could impact the NASA Safety Program.

1.16.2.6. Safety abatement plans as reported using the NASA Safety and Health Hazard Abatement Form (NF 1584) or equivalent if Headquarters advocacy is required to secure funding for abatement.

1.16.2.7. Copies of safety variances granted locally or at Program level (see Paragraph 1.20)

1.17 SAFETY LESSONS LEARNED

Safety lessons learned during the performance of management and technical functional activities shall be developed and disseminated to program managers and throughout NASA Centers and Headquarters by cognizant personnel to improve understanding of hazards, prevent the occurrence of accidents, and suggest better ways of implementing system safety programs. In addition to contributing appropriate information to the LLIS, safety managers will include this information in program, procurement, and Center newsletters to communicate more effectively with management. Lessons learned that indicate the need to revise source documents (e.g., Instructions, Handbooks, specifications, and standards) shall be submitted directly to the preparer of the document. The LLIS will provide a library of lessons learned data for use by Program Managers, design engineers, and safety personnel. Procedures for disseminating lessons learned can be found at the following Internet address:

http://llis.gsfc.nasa.gov/

1.18 NASA SAFETY REPORTING SYSTEM (NSRS)

The NSRS is a confidential, voluntary, and responsive safety reporting system that provides a direct channel for NASA employees and contractors to notify the NASA Safety and Risk Management Division of safety concerns. The NSRS enables safety personnel to identify safety problems and implement corrective actions independently. The nature of corrective actions may be engineering, manufacturing, administrative, procedural, or operational. Timely information about actual hazards is of the highest priority. The NSRS has been established to collect, evaluate, and communicate such information in a timely and accurate manner. It is intended to supplement, not replace, existing reporting systems. The NSRS will be implemented at all NASA Centers. NASA contractors are encouraged to implement the NSRS program at their facilities. (See Appendix B for NSRS Reporting Form). Pre-addressed, postage-paid forms can be obtained at any Center Safety Office. Forms should be mailed to:

NASA SAFETY REPORTING SYSTEM
PO BOX 6037
FALLS CHURCH, VA 22040-9824

1.19. SAFETY DOCUMENTATION

1.19.1. The goals of the NASA Safety and Risk Management Division documentation effort are to update and clarify top policy directives, separate policy from guidance, and reduce repetition and cross-linking between directives.

1.19.2. As a part of the documentation effort, the Safety and Mission Assurance DocumentationTree was developed and posted on the Internet at:

http://www.hq.nasa.gov/office/codeq/qdoc.pdf

1.19.3. The documentation tree represents the Safety and Mission Assurance top level NASA Policy Directives, NASA Procedures and Guideline Documents, applicable NASA Technical Standards, and other top level documents in the NASA Safety Program.

1.20. SAFETY VARIANCE (DEVIATION/WAIVER) POLICY

1.10.1 The primary objective of the NASA safety variance policy is to define the roles of both Headquarters and the Centers in such a way that Headquarters will maintain control over the requirements it sets while providing the Centers with the responsibility and freedom necessary to accomplish their tasks.

1.20.1.1. The following definitions apply to the NASA safety variance approval policy:

- Variance: Documented and approved permission to perform some act contrary to established requirements.

- Deviation: A variance that authorizes departure from a particular safety requirement where the intent of the requirement is being met through alternate means that provides an equal or greater level of safety.

- Waiver: A variance that authorizes departure from a specific safety requirement where an increased level of risk has been accepted.

1.20.1.2. NASA variances do not apply to Federal and applicable State/local regulations (e.g., OSHA, CalOSHA). These regulations apply to NASA operations in full. Any variance of a Federal or State/local regulation must be approved by the appropriate Federal/State/local agency (e.g., NASA Alternate Safety Standard for Suspended Load Operations approved by OSHA). The NASA Safety and Risk Management Division shall review all proposed variances of Federal regulations before submittal for approval.

- Shall: The word "shall" indicates that the rule is mandatory. Noncompliance with a "shall" statement requires approval of a variance. Use of the word "shall" is preferred when writing mandatory NASA safety requirements; however, the words "will" and "must" are used at times to indicate mandatory requirements and have the same interpretation as "shall."

- Should: The word "should" indicates that the rule is a recommendation, the advisability of which depends on the facts in each situation. Implementation of a "should" statement is at the discretion of the local officials.

1.20.1.3. The NASA Headquarters safety variance policy is provided in Table 1.1. It applies to all Headquarters safety requirements unless otherwise specified in the appropriate requirements document. Variance policies developed for specific safety programs shall follow this general policy as closely as possible.

1.20.1.4. When a variance is approved by Headquarters and is considered appropriate for use throughout the Agency, it shall be distributed as an interim change to the applicable Headquarters requirements document(s).

1.20.1.5 All requests for variance will be accompanied by rationale as to why the requirement can not be met, the risks involved, alternative means to reduce the hazard or risk, the duration of the variance, and comments from any affected employees or their representatives.

Table 1.1 - NASA Safety Variance Request and Approval Process Matrix

Type of Document	Wording	**Requirement Specified In:**	Routing	**Variance Approval Level**	**After Action Reporting Requirements**
Federal	Policy	n/a	Thru HQ NASA/QS	Federal Agency	
State	Policy	n/a	Thru Center Safety Director	State Agency	Info to HQ NASA/QS (Quarterly)
NPD	Policy	n/a	Thru Center Safety Director and Center Director	NASA HQ/QS	
NPG	Shall	n/a	Thru Center Safety Director	Center Director *	HQ NASA/QS (within 14 days)
NPG	Should	n/a		Center Safety Director	HQ NASA/QS (Quarterly)
NSS	Shall	NPD	Thru Center Safety Director and Center Director	NASA HQ/QS	
NSS	Shall	NPG	Thru Center Safety Director	Center Director *	HQ NASA/QS (within 14 days)
NSS	Should	n/a		Center Safety Director	Not required

Example: A ***variance request*** to a requirement stated in an ***NPG*** (fourth row of matrix) that uses the word ***shall*** would be routed ***through the Center Safety Director*** and ***approved or denied by the Center Director***. A copy would then be ***sent to HQ NASA/QS within 14days*** of the request along with the rationale for its approval.

* Approval at this level if certain document is not implementing Federal regulatory policy. In those cases, forward to HQ NASA/QS for waiver request to applicable Federal Agency.

CHAPTER 2: SAFETY REQUIREMENTS FOR NASA CONTRACTS AND CONTRACTOR OPERATIONS

2.1. PURPOSE

This chapter describes the general approach for safety programs and activities of NASA contractor operations. The chapter is not a direct instruction to contractors, but provides guidance for NASA officials with responsibility for assuring safety under NASA contracts.

2.2. APPLICABILITY AND SCOPE

This chapter reflects the minimum safety requirements, documentation, and procedures, if implemented via contract, which must be included in NASA contracts.

2.3. AUTHORITY AND RESPONSIBILITY

Safety responsibilities for NASA contracts and contractor operations will be coordinated among the program office, safety office, contracting office, and other offices as needed.

2.3.1. Program/Project Officials shall:

2.3.1.1. Ensure all procurement documentation, such as procurement requests, Requests for Proposal (RFP's)/Invitations for Bids, source evaluations, briefings, Statements of Work (SOW's), schedules, and proposed changes are reviewed from a safety standpoint consistent with the scope of the contract.

2.3.1.2. Coordinate with the cognizant safety officials and contract bidder to determine and approve the respective safety requirements and objectives under which the contract will be performed, including specifications, and specific tasks, and mandatory, non-negotiable, standards which will become contractually required.

2.3.1.3. Develop safety requirements and objectives that are clearly delineated in the specifications. Provide specific tasks to the contracting officer for incorporation into the contract as required.

2.3.1.4. Ensure performance of the required checks and inspections of contractor compliance with the safety requirements of the contract.

2.3.1.5. Tailor surveillance of contractor safety matters appropriate to the nature of the procurement.

2.3.2. Contracting Officers

Contracting Officers receive their direction from the Federal Acquisition Regulation (FAR) and the NASA FAR Supplement (NFS).

2.3.3 Safety Officials

The NFS outlines the role of the Center safety officials in support of procurement activities (see NPG 5100.4, "Federal Acquisition Regulation Supplement (NASA/FAR Supplement")).

2.3.4 Assistant Administrator for Procurement

The Assistant Administrator for Procurement shall:

2.3.4.1. Publish the appropriate standard safety clause in the NFS.

2.3.4.2. Consult with and obtain the concurrence of the Director, NASA Safety and Risk Management Division, concerning safety clause deviations requiring the approval of the Associate Administrator for Procurement in accordance with NFS Subpart 18-23.7004, "Contract Clause," and NFS Subpart 18-1.4, "Deviations From the FAR."

2.4 REQUIREMENTS

To ensure adequate safety programs, NASA safety requirements for contracts must be appropriate and effective. The following as a minimum is required:

2.4.1. Provisions for suspending work will be established in cases where safety considerations warrant such action, and will be included in the contract.

2.4.2. Contractors shall (as applicable) design, produce, or develop products or equipment, or manage facilities that can be operated and inhabited in compliance with NASA and OSHA standards without modifications or restrictive procedures.

2.4.3. Contractors shall maintain a safe work environment, including the provision of necessary protective clothing and equipment unless provided as Government Furnished Equipment (GFE). The contractor's compliance with NASA and OSHA safety standards will be contractually binding as prescribed by law.

2.4.4. Contractors shall provide the Contracting Officer with information on the use of any hazardous materials that could present a risk or hazard to NASA operations or personnel. The Contracting Officer or safety official will require copies of Material Safety Data Sheets (MSDS's) for new hazardous materials. Hazard analyses/safety risk assessment will be developed and provided to NASA for approval before the start of any hazardous deliverable work or support operations as directed by the Contracting Officer.

2.4.5. Contractors shall be required to submit appropriate safety documentation during the procurement process, e.g. corporate safety policies, implementation procedures, and draft program planning documents. The source evaluation board and source selection official will use these documents in evaluating how well the contractor's policies and implementation procedures meet the intent of Federal safety requirements.

2.4.6. Prior to contract start, the Contracting Officer or designee shall brief contractors on the local safety administrative requirements. These include but are not limited to: incident/accident reporting, base emergency evacuation procedures, fire reporting, medical emergency notification, hazardous material spill reporting and response, and hot work permit requirements. The Contracting Officer or designee shall also inform the contractor of any adjacent NASA and other contractor operations that could pose a hazard to their operation and employees.

2.4.7. When there are significant changes to contracts or when contracts are combined, safety requirements must be addressed in the transition or consolidation plans.

2.4.8. Contractors shall develop motivation, awareness, training, and certification programs for their employees in safety matters. This will include regularly scheduled safety meetings for supervisors, foremen, and employees. Training will be documented in accordance with NASA and OSHA requirements.

2.4.9. Contractors shall report safety data on mishaps, close calls, and lessons learned as required in NPG 8621.x (DRAFT), "NASA Procedures and Guidelines for Mishap, Reporting, Investigating, and Recordkeeping," and in accordance with OSHA requirements. Investigation of contractor mishaps will be performed in accordance with investigation procedures as specified in the contractor's safety plan. The Contracting Officer or the safety Contracting Officer's Technical Representative (COTR) will evaluate and verify implementation of corrective actions.

2.4.10. Contractors shall monitor and self-evaluate activities for compliance with the safety provisions or requirements of the contract. Contractor activities also will be properly monitored and evaluated by NASA officials (or delegated agencies). These safety program reviews will be conducted to note and correct any safety problems at an early stage.

2.4.11. Center Safety offices shall implement contractor safety surveillance and evaluation programs. The depth of insight and oversight employed will fit the extent of hazards and the importance of the program.

2.4.12. Contractors shall provide the Contracting Officer or safety officials with access to their activities to determine the adequacy of safety measures. Contractors shall also provide access for NASA Headquarters and Center safety program review teams for them to conduct selected announced and unannounced reviews of contractor operations.

2.4.13. Contractors collocated on-site at NASA facilities shall comply with Center safety and emergency planning requirements. Contractors shall document their emergency points of contact and safety responsibilities for all operations with safety implications.

2.4.14. Contractors shall document the "flow-down" of safety responsibilities between appropriate tiers (i.e., subcontractors).

2.5. CONTRACTOR RELATIONSHIPS WITH OSHA

2.5.1. Responsibility

NASA contractors are not relieved of their responsibility to comply with all applicable Federal and state OSHA requirements. NASA authorities will award work on the basis of contractor compliance with OSHA standards and Public Law 91-596, "Occupational Safety and Health Act." Contractors shall assess all Government Furnished Property (GFP) or Facilities (GFF) associated with the contract and advise the safety COTR of areas not in compliance with OSHA standards.

2.5.2. Access of State or Federal Compliance Safety and Health Officers.

Compliance safety and health officers are persons authorized by the OSHA, U.S. Department of Labor (DoL), to conduct inspections. Federal (OSHA) or state compliance safety and health officers will be allowed on NASA Centers to review and survey contractor operations and investigate mishaps. If the state does not have an DoL-approved Safety Plan or the Center is under exclusive Federal jurisdiction, only Federal compliance officers shall have the right of access to contractor operations. Unless exclusive Federal jurisdiction is claimed by Federal OSHA, both Federal and State OSHA investigators will be allowed to investigate a contractor mishap occurring on a NASA Center. The NASA Safety and Risk Management Division or Occupational Health Division as applicable and the DASHO will be notified of OSHA's (Federal or State) impending investigation and will be provided the results of their investigation.

2.5.3. Contractor Citations

Under Public Law 91-596, an employer is responsible for providing employees with safe working conditions regardless of where the employees are working. Thus, the contractor shall submit a timely reply to any OSHA citation received. The contractor is responsible for settling citations issued against the operation unless covered by subparagraph 5.4.

2.6. GRANTS

The safety special condition in research grants involving performance on certain NASA facilities GFE, or with hazardous or energetic materials or chemicals whose use may pose a significant safety or health risk is an integral part of the grant document. Before commencing work, the grantee shall submit a hazard assessment to the grants officer. Based upon the perceived risk, a safety and health program plan shall be developed by the grantee and approved by the grants officer or designee. The special condition requires the same mishap reporting and investigating requirements as contracts.

CHAPTER 3: SYSTEMS SAFETY

3.1. PURPOSE

This chapter establishes procedures and guidelines for the implementation of systems safety processes to ensure the identification and reduction of Program safety risks to an acceptable level to enhance mission success.

3.2. APPLICABILITY AND SCOPE

3.2.1. For simplicity, "Programs" shall be interpreted to include programs, projects, and acquisitions. When the work is performed in-house at NASA, the term Contractor shall be interpreted to apply to the in-house activity.

3.2.2. NASA requires systems safety tasks for systems acquisitions, in-house developments, facility design/modifications, and Agency operations and activities. For joint ventures between NASA and other parties including commercial services, interagency efforts, and international partnerships, application of these practices shall be as specified in related contracts, Memoranda of Understanding, NPD's, or other documents, and will consider the degree of NASA responsibility in the venture.

3.2.3. The Program manager in conjunction with the local Safety and Mission Assurance organization shall determine the degree to which specific procedures, guidelines, and requirements contained in this chapter are implemented. They shall consider the following: potential for personnel injury, mission failure, equipment loss or facility damage, property damage, impact to cost and schedule, and visibility to the public. The final mission success activity will be documented and approved as an element of the risk management portion of the program plan. (See NPG 7120.5A, paragraph 4.5.1.2)

3.2.4. Tailored system safety activities should be planned and documented during the formulation phase for the following:

3.2.4.1. Aeronautical systems.

3.2.4.2. Space flight systems (manned and unmanned).

3.2.4.3. Payloads (spacecraft, internal and external payloads and experiments flown on aircraft, Space Shuttles, International Space Station, Expendable Launch Vehicles (ELV's), balloons, and sounding rockets).

3.2.4.4. Facilities.

3.2.4.5. Support equipment, including ground and airborne, test, maintenance, and training equipment.

3.2.4.6. Related safety-critical software.

3.2.5. A systematic approach to safety should also be applied to operations and supporting activities, including: construction, fabrication, and manufacture; experimentation and test, packaging and transportation; storage, checkout, launch, flight, use, reentry, retrieval, and disassembly; maintenance and refurbishment, modification and disposal.

3.2.6. Programs with existing, approved system safety tasks containing adequate definition of the risk assessment and management process are not required to comply with any new requirements of this chapter, but any changes made in their system safety task must comply with this chapter. This chapter shall not supersede or prevent the application of more stringent requirements imposed by programs internally.

3.3. OBJECTIVE

The principal objective of a system safety activity is to provide for an organized, disciplined approach to the early identification and resolution of hazards impacting personnel, hardware, or mission success to a level as low as reasonably possible. The system safety activity will use the 5-step risk management approach (see NPG 7120.5A paragraph 4.2) which is:

3.3.1. Identify the system safety and mission success risks (hazards) early in the program and continue through out the PAPAC process. The PAPAC process is illustrated in Figure 3.1.

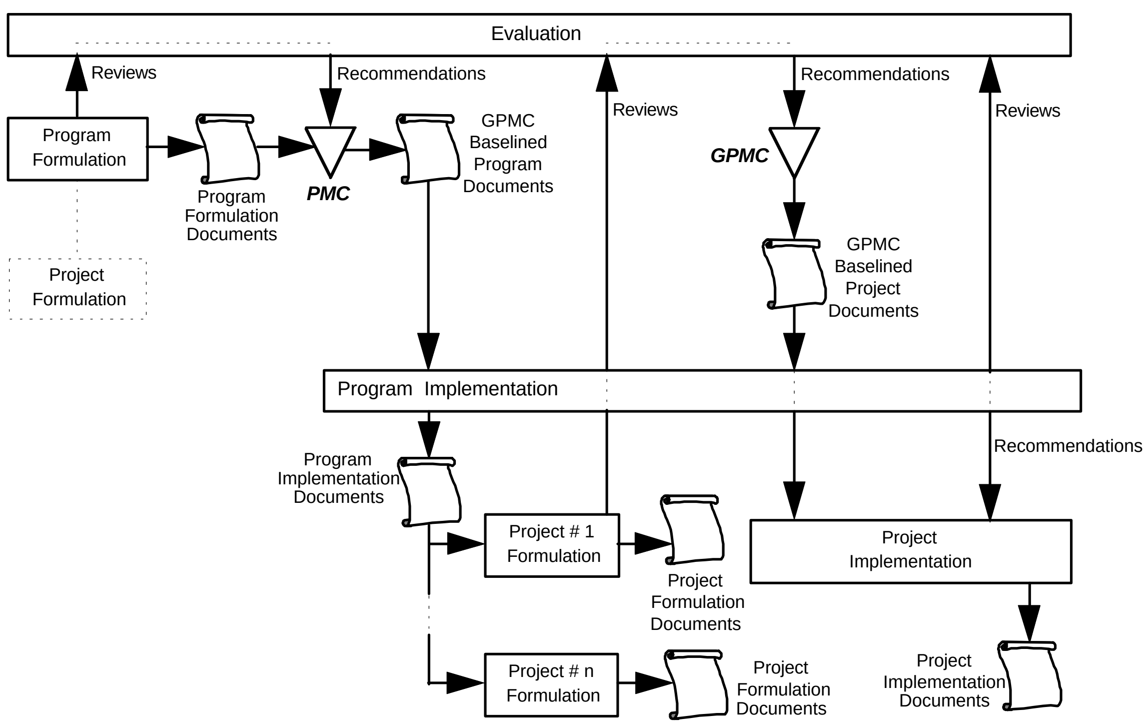

Figure 3.1 PAPAC Process

3.3.2. Analyze the risks (hazards) for probability, impact/severity, and time frame. When that is complete, prioritize the risks.

3.3.3. Plan what should be done to eliminate or reduce the risks, and provide the planning and decision making documentation to the appropriate levels of program management for a decision to eliminate, further reduce, or accept the risk. Institute hazard mitigation (corrective) actions.

3.3.4. Track the results of the corrective actions and continue to verify and validate their effectiveness.

3.3.5. Control or change the corrective action plans based on the monitoring of the mitigation actions.

3.4 HAZARD REDUCTION PROTOCOL

Hazards will be dispositoned according to the following prioritization scheme:

3.4.1. Eliminate hazards.

3.4.2. Design for minimum hazards.

3.4.3. Incorporate safety devices.

3.4.4. Provide caution and warning devices.

3.4.5. Develop administrative procedures and training.

(Note: providing protective clothing and equipment is considered an administrative procedure.)

3.5. RESPONSIBILITIES

3.5.1. NASA Program Managers shall:

3.5.1.1. Implement a system safety and mission success activity based on the loss potential of the Program and provide adequate resources to achieve the safety objectives. Depending upon program complexity, a typical program will require the equivalent of 3 to 5 percent of direct engineering and operations staff hours to support safety requirements.

3.5.1.2. Assign a System Safety Manager (SSM), in coordination with the Center Safety and Mission Assurance (SMA) Director, to have specific responsibility for executing the system safety task. The SSM will report to the Program Manager for program direction and to the Center Safety and Mission Assurance official for policy and functional direction.

3.5.1.3. NASA Program managers shall implement and maintain the system safety and mission success portion of the risk management activity of the program plan with guidance and assistance from the local Safety and Mission Assurance organization

3.5.1.4. Perform system safety and mission success oriented reviews of the program. The greater the potential risks (e.g. complexity or visibility of the programs), the greater the independence and formality of the review required. Major programs such as the Space Shuttle or the International Space Station will have dedicated independent assessment activities.

3.5.1.5. Perform system safety analyses appropriate to the Program and system safety oversight by NASA, based on recommendations from the SSM. Interact with the engineering, integration, and operations functions to ensure identified hazards are addressed at the earliest practicable time. The NASA Lessons Learned Information System, (LLIS) will be used to supplement the normal program hazard assessment process.

3.5.1.6. Establish a formal, closed loop, risk acceptance process to identify and track program hazards with residual risk. Ensure residual risks are accepted in writing. Only the Program Manager is permitted to accept residual critical and catastrophic safety risks identified in the system safety analysis process.

3.5.1.7. Ensure Program directives, specifications, and standards provide uniform and systematic application of safety policy and requirements.

3.5.1.8. Ensure sufficient numbers of personnel of appropriate experience and skills are assigned to perform system safety tasks. Provide training when necessary.

3.5.2. Assigned System Safety Managers shall:

3.5.2.1. Exhibit appropriate technical and managerial training and expertise for conducting an effective safety process.

3.5.2.2. Advise the Program Manager regarding NASA requirements for and status of the system safety task.

3.5.2.3. Manage the system safety task for the Program Manager by executing the following tasks:

- Assist the Program Manager in the development, documentation, and implementation of the system safety and mission success activity in the program plan.

- Organize the system safety effort to ensure maximum effectiveness in interacting with engineering, operations, integration, and Program management.

- Develop technical safety requirements and ensure their incorporation into Program requirements, specifications, and planning documents.

- Determine which required hazard analysis tools and techniques (see Appendix G) will be used to ensure compliance with NASA and Program safety policy and directives and when they will be used to produce safety and mission assurance documentation. Ensure the selected tools and techniques are used in an iterative process to identify all Program hazards, causes, detailed control requirements, and control verifications.

- Determine reporting requirements for all levels of the originating organization to support the system safety task, (i.e., contractor, element, or NASA organization). Establish criteria for submittal (milestone, periodic, event), format, and distribution, and ensure the program provides for submittal of the required reports.

3.5.2.4. Conduct periodic independent reviews of the system safety tasks keyed to Program milestones.

3.5.2.5. Assist and support outside, independent review groups chartered to provide independent assessment of the program.

3.5.2.6. Maintain an up-to-date database of identified hazards throughout the life of the Program.

3.5.2.7. Maintain safety oversight of the Program tests, operations, or activities at a level consistent with mishap potential for the life of the Program.

3.5.2.8. Use the independent safety reporting path to keep the OSMA apprised of the system safety status, particularly regarding problem areas that may require assistance from Headquarters.

3.5.2.9. Support the OSMA independent safety assessment process (e.g., Space Shuttle Pre-launch Assessment Reviews, International Space Station Design and Assessment Reviews) to determine readiness to conduct tests and operations having significant levels of safety risks, and provide real-time safety assessments to the OSMA, when appropriate, while tests and operations are in progress.

3.6. HAZARD ASSESSMENT

The Hazard Assessment Process is a principal factor in the understanding and management of risk. Hazards are identified and resultant risks are assessed by considering probability of occurrence and severity of consequence. Risk may be assessed qualitatively or quantitatively. System Safety is an integral part of the overall program risk management decision process.

3.6.1 <u>Risk Assessment Code (RAC)</u>.

The RAC is a numerical expression of risk determined by an evaluation of both the potential severity of a condition and the probability of its occurrence. The following definitions and Risk Assessment Code Matrix (Figure 3-2) are provided as guidance. Variations may be approved by the cognizant safety and program officials.

3.6.1.1. Severity is an assessment of the worst potential consequence, defined by degree of injury or property damage, which could occur. The severity classifications are defined as follows:

- Class I - Catastrophic - May cause death or mission failure.
- Class II - Critical - May cause severe injury or major property damage.
- Class III - Marginal - May cause minor occupational injury or illness or property damage.
- Class IV - Negligible - Probably would not affect personnel safety but is a violation of specific criteria.

3.6.1.2. Probability is the likelihood that an identified hazard will result in a mishap, based on an assessment of such factors as location, exposure in terms of cycles or hours of operation, and affected population. The following is as example of Probability Estimation:

- A - Likely to occur immediately. ($X > 10^{-1}$)
- B - Probably will occur in time. ($10^{-1} \geq X > 10^{-2}$)
- C - May occur in time. ($10^{-2} \geq X > 10^{-3}$)
- D - Unlikely to occur. ($10^{-3} \geq X > 10^{-6}$)
- E - Improbable to occur. ($10^{-6} \geq X$)

	PROBABILITY ESTIMATE				
SEVERITY CLASS	**A**	**B**	**C**	**D**	**E**
I	**1**	**1**	**2**	**3**	**4**
II	**1**	**2**	**3**	**4**	**5**
III	**2**	**3**	**4**	**5**	**6**
IV	**3**	**4**	**5**	**6**	**7**

Figure 3.2 Risk Assessment Code Matrix

3.7. SAFETY ACTIVITY PHASES

As presented in Figure 3.3, System Safety and Mission Success Hazard Analyses, the hazard analysis process begins in the formulation stage and continues, in varying degrees, throughout the program's life cycle. This involvement begins once the system allocation process has identified and assigned the functional responsibilities among the systems and subsystems for system design and development. The system safety and mission success hazard analysis effort must include continuing and iterative process to consider input as the system design progresses and matures.

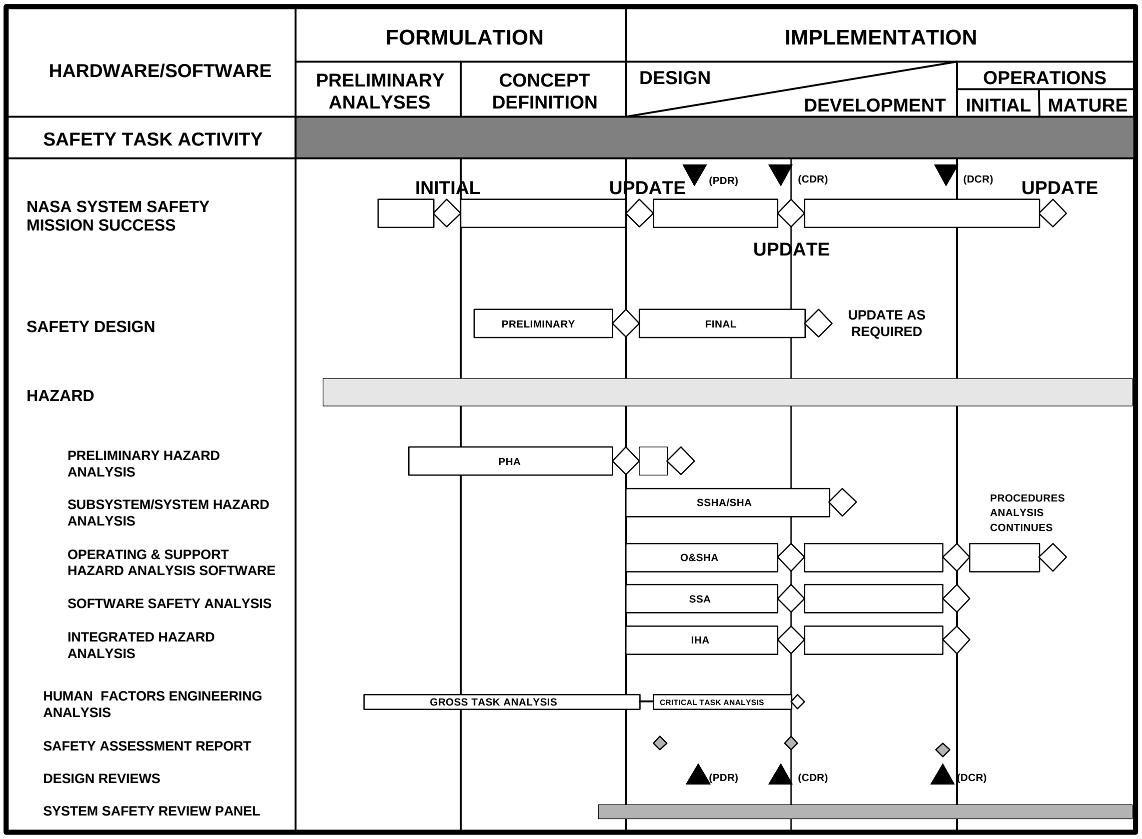

Figure 3.3 System Safety and Mission Success Hazard Analyses

3.8. SYSTEMS SAFETY AND MISSION SUCCESS HAZARD ANALYSES

3.8.1. Systems safety analyses provide a means to systematically and objectively identify hazards, determine their risk level, and suggest the mechanism for their elimination or control. This iterative process begins in the Conceptual Phase and extends throughout the life cycle including the Disposal Phase. The extent and depth of analysis required to meet the following five functions will be determined by system complexity and loss potential. Functions supported by the analyses include:

3.8.1.1. Providing the foundation for the development of safety criteria and requirements.

3.8.1.2. Determining whether and how the safety criteria and requirements provided to engineering have been included in the design.

3.8.1.3. Determining whether the safety criteria and requirements created for design and operations have provided an acceptable level of risk for the system.

3.8.1.4. Providing a partial means for developing pre-established safety goals.

3.8.1.5. Providing a means for demonstrating that safety goals have been met.

3.8.2. During the hazard identification process, it is essential to remain non-judgmental about the associated probability, severity, and corrective action. Once identified, rank hazards by severity, probability of occurrence, and program impact (risk assessment). Perform sufficient analyses to assess the likelihood of occurrence (usually qualitative for early assessments) for each undesired event identified.

3.8.3. There are several types of analyses necessary to identify all the hazards, some of which are specialized and others which, as designs mature, build on previously accomplished analyses.

3.8.3.1. The first safety analysis is the Preliminary Hazard Analysis (PHA), which shall be performed early. Other primary analyses shall include the Subsystem Hazard Analysis (SSHA), Software Hazard Analysis (SWHA), System Hazard Analysis (SHA), Operating and Support Hazard Analysis (O&SHA), Human Factors Engineering Analysis, the Safety Requirements Compliance Matrix, and Integration Hazard Analysis (IHA), unless otherwise indicated by the PHA. If possible, use theses analyses to offer recommendations to reduce risks, and provide benefit analysis when suggested changes are implemented.

3.8.3.2. The hazard analyses should use data developed by other types of analyses when available, such as the Failure Modes and Effects Analysis/Critical Items Lists (FMEA/CIL), Operations Analysis, Human Factors Engineering Analysis, and Maintainability Analysis. The safety analyst may have to develop specific, limited data to support the hazard analyses if the other analyses are not performed. See Appendix D for further information on these analysis processes and techniques.

3.9. SYSTEM SAFETY AND MISSION SUCCESS PROGRAM REVIEWS

The Program Manager, or his designated agent, shall conduct one or more system safety and mission success reviews depending on the complexity of the system. These reviews may be in conjunction with other program milestones . The purpose of these reviews is to evaluate the status of hazard analyses, residual risks, hazard controls, verification techniques, technical safety requirements, and program implementation throughout all the phases of the system life cycle. These reviews emphasize evaluation of management and technical documentation.

3.10. DOCUMENTATION

3.10.1. The system safety task requires creation and maintenance of documentation that provides ready traceability from the baseline safety requirements, criteria, and effort planned in the conceptual phases through the life cycle of the program. All pertinent details of the hazard analysis and review shall be traceable from the initial identification of the hazard through its resolution and any updates, until such time in the Program, as it is no longer applicable.

3.10.2. The safety analyst shall submit a report to management detailing the safety assessment to document the status of the system safety task.

3.10.2.1. Submit the report at milestones as may be required by the Program.

3.10.2.2. Summarize the work to date in terms of hazard analyses completed, Hazard Reports (HRs) submitted, significant safety assessments, tasks in progress, and tasks anticipated to begin before the next review.

3.10.2.3. List residual risks baselined and potential risks that have yet to be resolved.

3.10.2.4. Document management and technical changes that affect the established safety baseline.

3.10.2.5. To complete the audit trail, document and verify adequate resolution of the hazards and obtain written acceptance of the risk from the Program Manager.

3.11. CHANGE REVIEW

Systems are changed during their life to enhance capabilities, provide more efficient operation, and incorporate new technology. With each change, the original safety aspects of the system could be impacted, either increasing or reducing the risk. Any aspect of controlling a hazard could be weakened, new hazards could be created, or conversely, hazards could be eliminated. Even a change that appears inconsequential could have significant impact on the baseline risk of the system. Accordingly, subject proposed system changes to a safety review or analysis as appropriate to assess the safety impact; HRs will be updated when required to show any identified risk change. Each change initiator shall ensure that safety personnel assess the potential safety impact of the proposed change and any changes to the baseline risk. Changes proposed to correct a safety problem also shall be analyzed to determine the amount of safety improvement (or detriment) that would actually result from incorporation of the change.

3.12. PROCUREMENT

3.12.1. Include appropriate system safety requirements in procurement of design, development, fabrication, test or operations of systems, equipment, and facilities. System safety tasks shall be specific so the potential bidders will clearly understand the system safety requirements. Specific tasks provide a basis to evaluate bids for compliance with the safety requirements.

3.12.2. Safety and Mission Assurance personnel will:

3.12.2.1. Participate in the development of the system safety tasks.

3.12.2.2. Participate in on-site visits and pre-bid conferences to ensure potential bidders understand system safety provisions.

3.12.2.3. Provide safety input to the Source Evaluation Board.

3.12.2.4. Conduct independent assessments of contract system safety deliverables.

CHAPTER 4: SAFETY TRAINING AND PERSONNEL CERTIFICATION

4.1. PURPOSE

This chapter describes the requirements for establishing safety training programs and minimum training certification levels necessary for personnel involved in potentially hazardous NASA operations. Much of this training is available on the Internet through the Site for On-line Learning and Resources (SOLAR) at:

http://solar.msfc.nasa.gov

Instructor-based courses are available through the NASA Safety Training Center (NSTC). The NSTC can be reached by telephone at 281-244-1284.

4.2. APPLICABILITY AND SCOPE

This chapter applies to all NASA employees and to NASA contractors in support of NASA operations in accordance with the terms of the contract. This chapter is not a direct instruction to contractors, but provides guidance for NASA officials with responsibility for ensuring compliance for safety training programs and personnel certification within NASA contracts.

4.3. RESPONSIBILITIES

4.3.1. Annual Review

Each NASA Center will annually review all operations being performed at the Center to ensure that the implemented safety training program is working effectively and to identify and enter into the program all those jobs that are potentially hazardous in addition to the mandatory listing in paragraph 4.6. Employee safety committees, employee representatives, and other interested groups should be provided an opportunity to assist in the identification process.

4.3.2. Acceptance Standards

Delegated Agency personnel (e.g., Defense Contract Management Command (DCMC)) used to enforce NASA activities shall meet the training requirements of the delegation or the appropriate, accepted standards (e.g., DLAM 8280.1, "Specialized Safety Manual").

4.3.3. Training and Personnel Development Offices

Center training and personnel development offices, with assistance as needed from the Center Safety Officials, will be responsible for coordinating safety and certification training needs and overseeing those training efforts. Typical responsibilities are as follows:

4.3.3.1. Identification of training needs.

4.3.3.2. Identification of budget requirements for training.

4.3.3.3. Development of training courses and materials.

4.3.3.4. Assurance that training records reflect employee safety training.

4.3.4. Safety Office

Responsibility for overall development of required safety certification programs rest with the Center Safety Official. Each line organization is responsible for managing the certification program for its employees and contractors in accordance with procedures and guidelines in this document.

4.3.5. Medical Office

This Office oversees or conducts the required personnel medical examinations in support of the safety certification effort and ensures compliance with Occupational Safety and Health Administration (OSHA) and other Federal, State, and local agency medical monitoring and recordkeeping requirements. The Medical Office shall determine the depth, scope, and frequency of medical examinations. The Medical Office is also responsible for medical certification in health hazard and related activities.

4.3.6. NASA Headquarters.

The role of the NASA Safety and Risk Management Division will be to assist its Center counterparts in ensuring that 29 CFR Part 1960 requirements are followed and that appropriate Agency-wide uniformity exists in the NASA safety training program. The Safety and Risk Management Division will act as a clearinghouse for information regarding available safety training courses and materials and it will develop, in conjunction with the Training Development Division at NASA Headquarters, training courses suited to specific Agency safety needs. The NASA Safety and Risk Management Division, in conjunction with the Occupational Health Office, will co-develop training courses and materials in areas of overlapping regulatory or programmatic responsibility.

4.4. SAFETY TRAINING

Training must be provided to assist managers/supervisors and employees in their specific roles and responsibilities in the Safety programs. Executive Order 12196, "Occupational Safety and Health Programs for Federal Employees," dated February 26, 1980, and 29 CFR 1960 (Subpart H) require that NASA establish comprehensive safety training programs. See NPG 8715.1, "Safety and Health Handbook - Occupational Safety and Health Programs."

4.5. PLANNING AND IMPLEMENTATION

4.5.1. Safety Training Program.

A comprehensive safety training program will be formulated by each Center. The following should be considered in developing the safety training program for all employees:

4.5.1.1. Management commitment to establish and implement comprehensive safety training programs (ideally, this should be in the form of a policy statement issued by senior management).

4.5.1.2. Recognition of OSHA, NASA, National Fire Protection Association (NFPA), Federal Aviation Administration (FAA), Environmental Protection Agency (EPA), and other training requirements.

4.5.1.3. Identification of employee training groups within the Center population and determination of present training levels.

4.5.1.4. Identification of specific tasks, hazardous conditions, or specialized processes and equipment encountered by employees that would require safety training, e.g., certification training, cryogenic liquid carrier driver or hazardous waste operations, etc.

4.5.1.5. Identification and documentation of the planned training to be given to each employee category and the intended approach (course, literature, etc.). Refer to Appendix B for a suggested sample training schedule and career development plan.

4.5.1.6. Determination of the availability of safety training resources. A lack of a specific training resource will require the development of specialized training course materials.

4.5.1.7. Establishment of a training schedule.

4.5.1.8. Review, evaluation, and revision, if necessary.

4.5.2. Documentation. The Center Safety Office will maintain a current copy of the Center Safety Training Plan.

4.6. PERSONNEL SAFETY CERTIFICATION REQUIREMENTS FOR POTENTIALLY HAZARDOUS OPERATIONS AND MATERIALS

Many NASA operations involve hazardous or unusual chemicals, state-of-the-art technology, or inherent hazards to life, the environment, or property. People who perform or control hazardous operations or use or transport hazardous material must possess the necessary knowledge, skill, judgment, and physical ability (if specified in the job classification) to do the job safely, and be certified to do so. The following paragraphs prescribe personnel certification requirements.

4.6.1. Exclusions

4.6.1.1. This paragraph does not apply to personnel engaged in skill operations that already require certification by quality assurance organizations, such as soldering, brazing, crimping, potting, etc., or to personnel performing inspections using dye penetrant, magnetic particle, ultrasonic, radiograph, and magnaflux, etc.

4.6.1.2. Certification of equipment and facilities is not within the scope of this section but may be equally as important as personnel certification in relation to safety. Refer to other applicable chapters in this document for information concerning equipment and facilities certification.

4.6.1.3. This chapter shall not be used as a justification for allowing hazardous duty payments, environmental differential pay, or premium pay, nor will the fact that a job qualifies for hazardous duty pay imply that it is covered by this chapter. It has always been NASA safety policy to make all operations as safe as possible, including potentially hazardous testing. For guidance on hazard duty pay differentials, refer to 5 CFR 532, "Prevailing Rate System," 5 CFR 550, "Administrative Personnel, Office of Personnel and Management," and the Federal Personnel Manual.

4.6.2. Hazardous Operations Requiring Safety Certification.

Hazardous operation safety certification is required for those tasks that potentially have an immediate danger to the individual (death/injury to self) if not done correctly, or could create a danger to other individuals in the immediate area (death or injury), or are a danger to the environment. Detailed training and certifications requirements may be found in specific NASA-Standards, e.g., NASA-STD-8719.9, "NASA Lifting Devices and Equipment Manual," or NASA-STD-8719.12, "NASA Explosives Manual." Center safety officials or their designees can require additional hazardous operation safety certifications but must include the following:

4.6.2.1. Flight deck crew members (FAA licensing may not be sufficient).

4.6.2.2. Firefighters.

4.6.2.3. Propellant or explosive users per NASA-STD-8719.12.

4.6.2.4. Propellant or explosives handlers.

4.6.2.5. Rescue personnel.

4.6.2.6. Self-contained breathing apparatus (SCBA) users.

4.6.2.7. Self-contained underwater breathing apparatus (SCUBA) users.

4.6.2.8. High-voltage electricians (above 500 V).

4.6.2.9. Altitude chamber operators.

4.6.2.10. High-pressure liquid/vapor/gas system operators (above 150 psig).

4.6.2.11. Hyperbaric chamber operators.

4.6.2.12. Tank farm workers.

4.6.2.13. Wind tunnel operators.

4.6.2.14. Welders.

4.6.2.15. Laser operators/maintenance personnel.

4.6.2.16. Centrifuge operators.

4.6.2.17. Range Safety Officers.

4.6.2.18. Crane operators.

4.6.2.19. Riggers for hoisting operations.

4.6.2.20. Heavy equipment operators.

4.6.2.21. Confined space entry personnel.

4.6.3. Hazardous Materials Handlers Certification.

This safety certification is required for those individuals involved strictly with the handling, transport, or packaging of hazardous materials that will not otherwise disturb the integrity of the basic, properly packaged, shipping container that holds the hazardous material. Operations that involve the reduction of palletized or otherwise combined items of packaged hazardous materials qualify as handling.

4.7. CERTIFICATION REQUIREMENTS

All personnel engaged in potentially hazardous operations or hazardous material handling, as determined by line management or Center Safety Officials, will be certified as capable to operate the equipment or perform their jobs in a safe manner. All contractor personnel engaged in potentially hazardous operations or hazardous material handling shall fulfill these requirements.

4.7.1. For hazardous operation's certification, the following is required as a minimum:

4.7.1.1. Physical examination (see subparagraph c).

4.7.1.2. Initial training (classroom and/or on-the-job). Establish the level and structure of training according to the hazards of the job being performed.

4.7.1.3. Written examination (as needed).

4.7.1.4. Periodic refresher training needs as determined by the Center Safety Official, including review of emergency response procedures.

4.7.1.5. Recertification period. (as determined by the Center Safety Official, but shall not exceed a 4-year interval.)

4.7.2. For hazardous material handlers, the following is required as a minimum for certification:

4.7.2.1. Specific training in the Federal, NASA, and local rules for preparing, packaging, marking, and transporting hazardous material and/or equipment operation associated with the job. Drivers or operators of vehicles transporting hazardous materials shall be instructed in the specific hazards of the cargo or material in their vehicle and the standard emergency and first-aid procedures that should be followed in the event of a spill or exposure to the hazardous material. Training requirements can be found in 29 CFR 1910, "Code of Federal Regulations, Department of Labor (DoL), Occupational Safety and Health Standards," 40 CFR, and 49 CFR 177, "Code of Federal Regulations, Department of Transportation (DOT), Research and Special Programs Administration, Carriage by Public Highway." The risk of all hazardous chemicals produced or imported shall be evaluated. Information involving this risk must be transmitted to all employees in accordance with 29 CFR 1910.1200, "Hazard Communication," and NHS/IH-1845.3, "Hazard Communication."

4.7.2.2. Written examination (as needed) to determine the adequacy and retention of the training.

4.7.2.3. The recertification period will be as determined by the Center Safety Officials in the absence of any local, State, or Federal requirements.

4.7.3. Unless otherwise specified, the need for physical examinations for hazardous operations jobs, either to determine fitness for duty or to assist in establishing baseline or occupational exposure levels, will be as determined by the cognizant health official and will be in compliance with the applicable codes, regulations, and standards covering the occupation or environment. The need for fitness-for-duty examinations should be based on the hazardous consequences of employee's inability to perform the job correctly due to physical or mental deficiencies.

4.7.4. Personnel who are hazardous-operations-safety-certified or hazardous-material-handler-certified will be identified through the issuance of a card or license (to be carried on person) or a listing on a personnel certification roster. The roster indicates name, date, materials or operations for which certification is valid, name of certifying official, and date of expiration.

CHAPTER 5: NUCLEAR SAFETY FOR LAUNCHING OF RADIOACTIVE MATERIALS

5.1. PURPOSE

5.1.1. This chapter provides internal NASA procedural guidance for characterizing and reporting potential risks associated with a planned launch of radioactive materials into space on launch vehicles and spacecraft during normal or abnormal flight conditions. Procedures and levels of review and analysis required for nuclear launch approval vary with the risk and quantity of radioactive material planned for use.

5.1.2. An analysis or evaluation may be required in accordance with paragraph 9 of Presidential Directive/National Security Council Memorandum Number 25 (PD/NSC-25), "Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space," dated December 14, 1977, as revised on May 8, 1996, in obtaining nuclear launch safety approval. Guidance on procedures, requirements, or licensing details for using, storing, shipping, or handling radioactive materials in ground-based facilities or activities or in preparation for space uses are not included in this chapter. The tracking of radiation exposures to workers is also not included in this Chapter.

5.2. GUIDELINE OVERVIEW

5.2.1. Compliance with space nuclear launch safety processes is the responsibility of senior NASA officials involved with the control and processing of radioactive materials for launch into space. Acceptability of the potential risk of launching and use of nuclear materials in space is determined by the NASA Administrator or designee, as appropriate.

5.2.2. Basic designs of vehicles, spacecraft and systems utilizing radioactive materials should provide protection to the public, the environment, and users such that radiation doses resulting from exposures to the radiation sources are As Low As Reasonably Achievable (ALARA). Nuclear safety considerations shall be incorporated from the initial design stages throughout all project stages to ensure the overall mission health risk is acceptable.

5.2.3. All space flight equipment (including medical and other experimental uses) that contain or use radioactive materials shall be identified and analyzed (per Section 5.4) to identify the degree of introduced radiological risk.

5.2.4. NASA shall develop or ensure development of site-specific ground operations and radiological contingency plans commensurate with the risk represented by the planned launch of nuclear materials. Contingency planning, as required by the Federal Radiological Emergency Response Plan, will include provisions for emergency response, including support for source recovery efforts. NPD 8710.1, “NASA Emergency Preparedness Program Policy” and NPG 8715.x, “NASA Emergency Preparedness Plan” address the NASA Emergency Preparedness Policy and Program Requirements.

5.2.5. NASA shall apply the range safety requirements, with regards to safe launching of radioactive materials, specified in range safety standards (e.g.; Eastern and Western Range Regulation 127-1).

5.3. RESPONSIBILITIES

5.3.1. The NASA Headquarters Office of Safety and Mission Assurance (OSMA) shall:

5.3.1.1. Ensure that launches of radioactive materials are in accordance with paragraph 9 of PD/NSC-25, as applicable.

5.3.1.2. Assist in the reviews or evaluations of nuclear safety.

5.3.1.3. Ensure appropriate coordination with the Federal Emergency Management Agency to provide adequate emergency and recovery planning for all NASA missions with greater than an A_2 mission multiple of 100 as defined in Section 5.4.2.

5.3.1.4. Ensure that radiological emergency and recovery plans are developed and ensure their implementation where NASA is the Lead Federal Agency, as defined by the Federal Radiological Emergency Response Plan.

5.3.1.5. Prepare, coordinate, and provide the required notification of planned launches of radioactive materials to the Executive Office of the President, Office of Science and Technology Policy (OSTP).

5.3.1.6. Designate a Nuclear Flight Safety Assurance Manager (NFSAM), and a NASA Interagency Nuclear Safety Review Panel (INSRP) Coordinator; and provide for the support to assist the program/project offices in meeting the required nuclear launch safety analysis/evaluation. The NFSAM and INSRP coordinators shall be separate individuals. The appointment of the NFSAM and INSRP Coordinator shall be concurred on by the affected enterprises.

5.3.2. Program/Project Offices shall:

5.3.2.1. Designate an individual responsible for nuclear launch safety approval in accordance with paragraph 9 of PD/NCS-25.

5.3.2.2. Confer with the NASA Headquarters NFSAM as soon as radioactive sources are identified, even if only tentatively, for use on NASA spacecraft to initiate and schedule the nuclear launch safety approval activities.

5.3.2.3. Identify the amount of radiological material and applicable process for documenting the risk represented by the use of radioactive materials planned for use on the launch in accordance with Section 5.4 and provide required reports in accordance with Section 5.5.

5.3.2.4. Develop the nuclear safety analyses and obtain nuclear launch safety approval or launch concurrence or approval in accordance with section 5.4 as required.

5.3.3. NASA Centers, Facilities and Laboratories shall:

5.3.3.1. Ensure, to the extent of responsibility applicable under defined licensing/permitting documentation or agreements, compliance with all pertinent directives, licenses, agreements, and requirements promulgated by appropriate regulatory agencies relative to the use of radioactive materials planned for a space launch.

5.3.3.2. Ensure Radioactive Sources Reports that are submitted per Section 5.5.2 contain all radioactive sources intended for flight, which are under control of that Center.

5.3.4. NASA Launch and Landing Sites, in addition to the responsibilities of NASA Centers, Facilities, and Laboratories as per Section 5.3.3, shall:

5.3.4.1. For planned launches or landings of all radioactive sources from or on US territories or possessions:

- Develop and implement site-specific ground operations and radiological contingency plans to address potential ground handling accidents and potential launch/landing accident scenarios, and to support source recovery operations commensurate with the radioactive materials present.

- Exercise contingency response capabilities as deemed necessary to ensure adequate readiness of participants and adequacy of planning to protect the public, site personnel, and facilities.

- Ensure appropriate and timely coordination with regional Federal, State and local emergency management authorities to provide for support to and coordination with offsite emergency response elements.

- Make provisions for special off-site monitoring and assistance in recovery if radioactive materials could spread into areas outside the geographical boundaries of the launch site.

5.3.4.2. Establish a Radiological Control Center (RADCC) for launches and landings with radioactive sources possessing a significant health or environmental risk, or having an activity of A_2 mission multiple greater than 1000 as determined per Section 5.4.2, or as specified in applicable interagency agreements. The RADCC will provide technical support and coordination with other Federal/state/local agencies in case of a launch or landing accident that may result in the release of radioactive materials. Staff the RADCC commensurate with the risk associated with the radioactive materials present. The RADCC shall be operational during launch and landing phases anytime there is a potential for an accident that could release radioactive material.

5.3.5. When an Interagency Nuclear Safety Review Panel (INSRP) is meeting per Section 5.4.8, the NASA INSRP Coordinator shall:

5.3.5.1. Coordinate NASA's participation in activities required for the generation of the Safety Evaluation Report (SER) including coordination with Program/Project personnel to ensure adequate information is available to the INSRP.

5.3.5.2. Make arrangements for NASA employees to provide technical advice to the INSRP and coordinate the support needs of those selected (i.e.; travel, funding, technical) as necessary with NASA Headquarters Offices and through the NASA Center, Facility and Laboratory Directors, as may be appropriate.

5.4 THE NUCLEAR LAUNCH SAFETY APPROVAL PROCESS

5.4.1. The level of analysis, evaluation, review, and concurrence or approval required for radiological risk assessment varies with the total activity of radioactive materials planned for launch as follows:

5.4.1.1. For all planned launches of radioactive materials, the A_2 mission multiple value shall be used to determine the level of assessment required.

- The NASA office responsible for the mission shall inform the NFSAM as soon as radioactive material is identified for potential use. Notification shall consist of the information contained in the report format described in Section 5.5.2. This notification is required for NASA payload launches, on NASA launch vehicles, and when NASA facilities or sites are used.

- For launches by other countries from non-United State (U.S.) territories or possessions, in which NASA participates, if the launch vehicle or spacecraft contains a radiological source, the Program/Project Office shall consult with the NFSAM and the Office of the NASA General Counsel to determine what a provisions, if any, of this chapter apply.

- The total mission radioactive material activity shall be determined for all radioactive materials contained on the launch to calculate the total A_2 mission multiple per Section 5.4.2. The A_2 mission multiple shall be the highest of the algebraic sum of isotopes' A_2 multiples:

  - At launch,

  - Anytime the spacecraft will be in earth orbit, or

  - During near earth interplanetary flight (e.g.; Earth Gravity Assists).

5.4.2. Determination of A_2 Mission Multiple

The A_2 multiplier for each radioactive source shall be based upon the International Atomic Energy Agency (IAEA), Safety Series Number 6, Regulations for the Safe Transport of Radioactive Material, 1985 Edition as amended in 1990, Section III, paragraphs 301 through 306, and then summed to determine the A_2 mission multiple. Table I contains the referenced IAEA document section which tabulates the A_2 values for specific isotopes and forms of radioactive material. Except as noted, for radioisotopes whose A_2 limit in Table I is "Unlimited" or is unlisted, the value of 3.7×10^{-2} teraBequerals (TBq) (1.0 Curies (Ci)) shall be used as the A_2 value. Exceptions are Sm-147 which shall use 9×10^{-4} TBq (0.024 Ci) and Th-232 which shall use 9×10^{-5} TBq (0.0024 Ci) as their respective A_2 values.

The A_2 mission multiple shall be determined as follows:

$$A_2 \text{ Mission Multiple} = \sum_n \frac{(\text{RadioactiveSource}_n \text{ Activity})}{(\text{Source}_n \text{ Isotopic } A_2 \text{ Value})}$$

where n is for each source or line on the reports in Section 5.5.2 for each radioactive material on the launch vehicle and spacecraft.

5.4.3. Sections 5.4.4 through 5.4.7 describe the internal NASA nuclear launch safety process. Table 5.1 provides a summary of the reviews

Table 5.1: Nuclear Launch Safety Approval Summary

A_2 Mission Multiple	Launch Reported to NFSAM	Launch Concurrence/ Approval by	Launch Reported to OSTP	Required Level of Review and Reports	Approval/ Concurrence
$A_2 < 0.001$	yes	NFSAM	no	Section 5.5.1 Report	Concurrence letter from NFSAM
$0.001 \leq A_2 < 10$	yes	NFSAM	yes	Section 5.5.1 Report	Concurrence letter from NFSAM
$10 \leq A_2 < 500$	yes	AA/OSMA	yes	Section 5.5.1 Report, Nuclear Safety Review	Concurrence letter from AA/OSMA
$500 \leq A_2 < 1000$	yes	NASA Administrator	yes	Section 5.5.1 Report, Safety Analysis Summary	Approval letter from NASA Administrator
$1000 \leq A_2$	yes	Executive Office of the President	yes	Section 5.5.1 Report, Safety Analysis Report (program) Safety Evaluation Report (INSRP)	NASA Administrator requests approval via Director OSTP

5.4.4. For launches with A_2 mission multiples of less than 0.001 (in addition to requirements in Section 5.4.1), the Program Manager shall submit the report required by Section 5.5.2 to the

NFSAM. The report should be submitted a minimum of four months prior to launch as a part of the launch safety review process. The NFSAM will review the report and will inform the Program Manager in writing of concurrence/non-concurrence and any safety concerns prior to launch.

5.4.5. For launches with A_2 mission multiples of between 0.001 and 10 (in addition to the requirements in Section 5.4.1), the Program Manager shall request nuclear launch safety concurrence in writing. The request should be submitted to the NFSAM and shall consist of the report required by Section 5.5.2. The NFSAM will review the request and will inform the Program Manager in writing of nuclear launch safety concurrence/non-concurrence and any safety concerns. Launches of these quantities of radioactive materials are reported quarterly to OSTP by the NFSAM.

5.4.6. For launches with $A_{2,}$ mission multiples of between 10 and 500 (in addition to the requirements contained in Section 5.4.1):

5.4.6.1. Notification that a planned launch may contain radioactive materials in this range shall be made to the NFSAM and shall consist of the information contained in the Radioactive Sources Report required by Section 5.5.2, as a minimum. The report should be made as soon as the program identifies (even tentatively) radioactive materials for potential use.

5.4.6.2. The NFSAM, in consultation with the Program Manager, shall make a preliminary scoping of the radiological risk to identify the extent of analyses needed as part of a pre-launch nuclear safety review. The NFSAM and the Program Manager shall determine a mutually agreed schedule for developing a nuclear safety review.

5.4.6.3. The Program Manager shall prepare or have prepared a nuclear safety review of the radiological risk of the proposed mission. The review shall contain as a minimum:

- The report described in Section 5.5.2,
- Program excerpts describing the mission,
- Probability of launch and in-flight accidents which could result in release of radioactive materials on the Earth;
- Reasonable upper bound of health and environmental effects due to a radioactive material release;
- Mission specific information recommended for consideration in the launch or potential accident site's emergency response and clean-up planning (i.e.; license and special handling).

5.4.6.4. Provide the review to the AA/OSMA with a request for nuclear safety launch concurrence. The request should be made approximately five months prior to launch.

5.4.6.5. The NFSAM shall notify OSTP of the planned launch as a part of the quarterly report of planned launches.

5.4.7. For launches with A_2 mission multiples of between 100 and 1000 (in addition to the requirements contained in Section 5.4.1):

5.4.7.1. Notification that a planned launch may contain radiological materials in this range shall be made to the NFSAM and shall consist of the information contained in the Radioactive Sources Report required by Section 5.5.2 as a minimum. The report should be made as soon as the program identifies radioactive materials for potential use.

5.4.7.2. The NFSAM shall make a preliminary assessment of the radiological risk and provide a written assessment to the Program Manager. The NFSAM and the Program Manager shall determine a mutually agreed schedule for nuclear launch safety analyses and review activities to be conducted to support a nuclear launch safety concurrence request.

5.4.7.3. The Program Manager shall prepare a Safety Analysis Summary (SAS) in coordination with the NFSAM addressing the radiological risk of the proposed mission. The level of detail in the SAS will be commensurate with the radiological risk. The Program is encouraged to use other program documentation to provide mission and potential accident information in the SAS. As a minimum, the SAS shall contain:

- Brief descriptions of the planned mission, schedule, launch vehicle, and spacecraft to include operations while in-orbit and during near-earth flight.

- Description of all radioactive materials, their physical state/chemical form, and quantities.

- Brief descriptions, probabilities, and resulting consequences of launch and in-flight accidents that could result in release of radiological materials on the Earth.

- Estimate of any health and environmental effects due to a radioactive material release.

- Mission specific information recommended for consideration in the launch or potential accident site's emergency response and clean-up planning (i.e.; license and special handling).

5.4.7.4. The NFSAM shall review the SAS and provide timely comments to the Program, in accordance with the mutually agreed schedule. Approximately five months prior to launch, the SAS shall be forwarded to the NASA Administrator by the program, with concurrence of the AA/OSMA, with a request for nuclear launch safety approval from the NASA Administrator.

5.4.7.5. The NFSAM shall notify OSTP of the planned launch as a part of the quarterly report of planned launches.

5.4.8. For launches with A_2 mission multiples exceeding 1000 (in addition to requirements in Section 5.4.1):

5.4.8.1. Notification that a planned launch may contain radioactive materials in this range shall be made to the NFSAM and shall consist of the information contained in the Radioactive Sources Report required by Section 5.5.2 as a minimum. The report should be made as soon as the program identifies radioactive materials for potential use.

5.4.8.2. The Program Manager in coordination with the OSMA shall request from the NASA Administrator impanelment of an INSRP for that mission. INSRP impanelment should occur soon after the program identifies radioactive materials for potential use. The time required for an INSRP can be lengthy and must be factored into the program master schedule. The membership and responsibilities of the impanelled INSRP shall be in accordance with PD/NSC-25.

5.4.8.3. The Program Manager shall prepare or have prepared a Safety Analysis Report (SAR). The level of detail and content of the SAR will be commensurate with the mission radiological risk. In cases where DOE provides the radioactive material, the DOE programmatic SAR may be adopted to satisfy this requirement, in accordance with the interagency agreement(s) for specific missions. In cases where launch vehicles, configuration and radioactive materials are similar, the Program Manager, in consultation with the NFSAM and the INSRP is encouraged to use a comparative analysis based upon previous mission(s) safety analyses that bound the anticipated risk for the new mission. Where radioactive materials are being provided from multiple sources, the Program Manager may provide a single or multiple SAR/SAS documents to best meet this requirement.

5.4.8.4. The Program Manager is encouraged to begin coordination with the impaneled INSRP in the early stages of mission development. The Program Manager should invite the INSRP to review the development of launch and mission accident scenarios, probabilities of occurrence, dispersion, specification of associated environments, and health effects via documentation and program safety reviews. The INSRP normally reviews and evaluates all program documentation associated with the radioactive material safety for completeness and defensibility. The INSERP evaluation is documented in an Safety Evaluation Report (SER). The INSRP is normally assisted in their evaluation effort by expert consultants in various special areas from a number of Government agencies, national laboratories, industry, and academia.

5.4.8.5. The SAR shall be delivered to the INSRP according to a schedule mutually agreed upon by the INSRP and the Program Manager with the understanding that a SER should be completed four months or more before launch. The mutually agreed upon schedule should address the planned analyses schedule, base assumptions, analysis limitations/bounds and model descriptions associated with the SAR development. Interim reviews should be held to review all individual analyses prior to completion and provide status of evaluations of analyses as of a given date.

5.4.8.6. The INSRP prepares a SER of the radiological risk analyzed in the SAR. The SER, along with the SAR and other related documents, are considered by the NASA Administrator before requesting nuclear launch safety approval in accordance with PD/NSC-25.

5.4.9. For any orbiting spacecraft being resupplied or modified in which the U.S. Government is the lead (e.g.; International Space Station), a nuclear launch/safety approval for a mission is required when the total onboard A_2 Mission Multiple will exceed 10 for the orbiting spacecraft. Safety analyses and reviews shall be performed to the level of detail and launch concurrence/approval requirements as defined in Section 5.4.7 for in-flight accidents. An INSRP shall only be required when the A_2 Mission Multiple will exceed 1000 per Section 5.4.8.

5.5. REPORT REQUIREMENTS

5.5.1. Nuclear launch safety analyses (e.g.; SAS, SAR) and evaluation (e.g., SER) are described in the previous sections.

5.5.2. Radioactive Sources Report

The Radioactive Sources Report shall be used by NASA program/project offices and NASA Centers/Facilities/Laboratories to report planned launches of radioactive materials and request for nuclear launch concurrence/approval. The NFSAM shall use this report format to inform OSTP of planned launches. Figures 5.1 and 5.2 show the format for the reports for planned launch and for resupplying radioactive materials to on-orbit spacecraft. Entries shall be made for each isotope source. Isotopes of similar size, chemical form and activity level may be combined on a single line entry.

Vehicle/ Spacecraft	**Planned Launch Date**	**Launch Site**	**Number of Sources**	**Isotope**	**Total Activity (Ci)**	**A_2 Limit for Isotope (Ci)**	**A_2 Multiple for Each Isotope Source**	**Remarks**
	(Use one line for each isotope type, size and form)							
	(Use one line to sum the A_2 mission multiples for each mission)							

Figure 5.1: Planned Launches of Radioactive Materials Report

Figure 5.2 shows the format for the report for orbiting spacecraft which are resupplied (e.g.; Space Station).

Isotope	**Date Arrived On-Board**	**Number of Sources**	**Total Activity at Arrival (Ci)**	**Isotope Half-life**	**Activity as of Mission Start (Ci)**	**A_2 Limit for Isotope (Ci)**	**Current A_2 Multiple for Each Isotope Source**	**Remarks**
	(Use one line for each isotope type, size, form, and arrival date)							
	(Use one line to sum the A_2 mission multiples for the spacecraft)							

Figure 5.2: Radioactive Materials On-Board Report

The Activity and Fissile Material Limits table is located in Appendix D.

CHAPTER 6: OPERATIONAL SAFETY

6.1. PURPOSE

This chapter establishes safety procedures for NASA's Operational Safety program.

6.2. APPLICABILITY AND SCOPE

The requirements of this chapter apply to all NASA organizations, programs, facilities, and contractors in accordance with the terms of the contract.

6.3. OBJECTIVES

This objective of this chapter is to protect flight, ground, laboratory, and underwater personnel; craft; payloads; the public; property; and the environment from operations-related safety hazards. This is not inclusive of all regulations and requirements governing operations; therefore, references are indicated liberally throughout the text for detailed or working standards, specifications, and other references.

6.4. MOTOR VEHICLE SAFETY

Each Center shall enact regulations that are in compliance with applicable Federal, State, and local motor vehicle safety regulations.

6.4.1. Motor Vehicle Operation

6.4.1.1. Operators of motor vehicles shall not drive a motor vehicle for a continuous period of more than 10 hours, including non-NASA driving; nor shall the combined duty period exceed 12 hours in any 24-hour period, without at least 8 consecutive hours of rest. Variation in the above policy requires documented Center Safety Office approval.

6.4.1.2. If operation of the vehicle involves skills beyond those associated with normal, everyday operation of private motor vehicles, formal initial training, consisting of both classroom and operational testing, shall be conducted to ensure operator proficiency. Refresher training and testing shall be accomplished periodically as determined by the Center Safety Office.

6.4.1.3. All NASA motor vehicles used off NASA Centers shall be inspected to the standards of the State or other jurisdiction’s vehicle safety inspection requirements.

6.4.2. Safety Belts

Safety belts (seat belts) are required to be installed in all NASA owned and operated passenger cars, multipurpose passenger vehicles, trucks, and buses in accordance with the requirements of Executive Order 12566 and 49 CFR 571. The number of occupants in a NASA vehicle is limited to vehicle-rated occupancy.

The use of seatbelts by Federal employees while on official business is promulgated in Section 1 of Executive Order (E.O.) 13043. The E.O. states that "Seatbelt use is required by Federal employees whether they are at a contractor's facility, operating or in a Federally owned vehicle, or anywhere in the United States operating any vehicle while on Federal business." As long as these employees are Federal employees and representing the Federal government in that capacity, they are required to use seatbelts. All NASA employees shall comply with this mandatory requirement while travelling on official business.

6.4.2.1. Children unable to use the safety belts will be secured in DOT-approved child safety seats.

6.4.2.2. It is forbidden to carry passengers in the cargo area of pickup trucks flatbeds or special purpose equipment such as fire trucks or escape trucks unless designated occupant positions are provided (see 49 CFR 571.207) and required safety belts are provided.

6.4.2.3. All occupants of motor vehicles operated on NASA property, including delivery vans and trucks of all sizes will have the safety belt properly fastened at all times the vehicle is in motion.

6.4.3. Annual Seatbelt Report

6.4.3.1. NASA is required by E.O. 13043 to prepare an annual status report to the Secretary of Transportation on NASA-wide seat belt use. The report includes seat belt usage rates and statistics of crashes, injuries, and related costs involving Federal employees on official business. The NASA Safety and Risk Management Division is responsible for the preparation and submittal of the report to DOT. DOT consolidates this data into an annual status report to the President for all Federal Agencies.

6.4.3.2. Coordinate data for the annual report with the Headquarters Office of Management Systems and Facilities, Security, Logistics, Aircraft, and Industrial Relations Division and the Office of Life and Microgravity Sciences and Applications, Aerospace Medicine Division. The format and submittal date for the report will be as directed each year by the Secretary of Transportation. Collect seat belt use rate data from mandatory visual spot inspections at NASA Headquarters and Centers. Provide a summary of this data to Code QS 30-days prior to the submittal date of the compiled NASA report to the Secretary of Transportation. Annual vehicular accident statistical data reporting and collection throughout the NASA is implemented via the Incident Reporting and Information System (IRIS).

6.4.4. Traffic Control Devices and Markings

American National Standard Institute (ANSI) D6.1, "Manual on Uniform Traffic Control Devices for Streets and Highways," shall be used for guidance when setting traffic control devices or marking roads for motor vehicle operations on NASA property.

6.5. PROTECTIVE CLOTHING AND EQUIPMENT

6.5.1. General

Protective Clothing and Equipment (PCE) shall be issued to NASA employees at government expense in those situations where engineering controls, management controls, or other corrective actions have not reduced the hazard to an acceptable level or where use of engineering controls, management controls, or other techniques are not feasible.

6.5.2. Procurement

6.5.2.1. Center Directors and the Associate Administrator for Headquarters Operations are authorized to purchase PCE after the purchase request has been reviewed by safety and health professionals to determine proper specifications and adequacy of abatement. It is recommended that local safety and health committees be involved in the decision.

6.5.2.2. The authority for the purchase of PCE with appropriated funds is Public Law 97-258, 5 U.S.C. 7903, "Protective Clothing and Equipment" (September 13, 1982, 96 Stat.1063).

6.5.2.3. Only clothing and equipment meeting Federal regulations, industrial standards, or NASA special testing requirements shall be used.

6.5.3. Issuance

6.5.3.1. PCE shall be issued to all NASA employees exposed to hazards in accordance with subparagraph a. Accountability shall be in accordance with NPG 4200.1, "NASA Equipment Management Manual." Transients or visitors may be furnished PCE on a temporary basis if they are on site for NASA-related business purposes or at NASA's invitation. The host, guide, or area supervisor shall be responsible for obtaining, issuing, and recovering the PCE. Other non-NASA, contractor, and non-contractor personnel must procure their own PCE to provide an equivalent level of safety as required by NASA. (See paragraph 2.4.3.)

6.5.3.2. PCE shall be provided, used, stored, and maintained in accordance with 29 CFR 1910.132 through 1910.137 and stocked and issued as specifically directed in NPG 4100.1, "NASA Materials Inventory Management Manual."

6.5.4. Examples of PCE.

Items which may be purchased and issued by NASA include, but are not limited to, the following:

6.5.4.1. Safety goggles and safety spectacles (plain and prescription).

6.5.4.2. Welding helmets and shields.

6.5.4.3. Safety shoes.

6.5.4.4. Steel sole and/or toe safety boots.

6.5.4.5. Aprons, suits, and gloves (e.g., fire resistant materials, leather, rubber, cotton, and synthetics).

6.5.4.6. Protective head gear (e.g., hard hats and caps, liners, helmets, and hoods).

6.5.4.7. Barricades, traffic cones, flags, scaffolds, warning signs, alarms, lights, shields, and other public protective devices.

6.5.4.8. Face shields.

6.5.4.9. Specialty items of protective nature (e.g., cryogenic handlers suits, scape suits, fire fighter suits, foul weather gear, harnesses, life belts, lifelines, life nets, insulated clothing for "cold test" exposure, supplied air suits, and electrical protective devices).

6.5.4.10. Concentration alarms, toxic gas indicators, explosive gas indicators.

6.5.5. Health Related PCE.

Guidance for purchasing respiratory protective devices and other health-related PCE shall be issued by the NASA Occupational Health Office.

6.6. CONTROL OF HAZARDOUS ENERGY (LOCKOUT/TAGOUT PROGRAM)

NASA will meet or exceed OSHA minimum performance requirements for the control of hazardous energy as outlined in 29 CFR 1910.147. All NASA Centers shall establish a program for controlling hazardous energy during service and maintenance operations where the unexpected energizing or startup of equipment could cause injury to employees or equipment damage. The Center programs shall comply with all aspects of 29 CFR 1910.147 for electrical, pressure, hydraulic, pneumatic, and mechanical systems as a minimum.

6.7. PRESSURE AND VACUUM SYSTEMS SAFETY

NASA's program for ensuring the structural integrity of pressure vessels and pressurized systems (PV/S) and minimizing the associated mishap potential is outlined in NPD 8710.5, "NASA Policy for Pressure Vessels and Pressurized Systems." This NPD assigns responsibilities for the various aspects of the program; references the codes, standards, guides, and Federal regulations that must be followed; and establishes unique NASA requirements in areas such as certification/recertification, documentation, configuration management, and operator training/certification. The NPD also addresses flight systems qualification and acceptance.

6.8. ELECTRICAL SAFETY

This paragraph provides directives for protecting persons and property from electrical hazards. It applies to all NASA uses of electrical power.

6.8.1. <u>Hazards</u>.

Electrical systems shall be designed in accordance with the National Electric Code or MIL-STD 454, "Standard General Requirements for Electronic Equipment." Electrical systems shall be operated, and maintained to adequately control hazards that are likely to cause death or serious physical harm or severe system damage. All electrical systems shall be reviewed by the Center’s Safety Office, for appropriate location and for proximity of ignitable or combustible properties of material such as gas, vapor, dust, or fiber.

6.8.2. <u>Requirements</u>

6.8.2.1. All work shall be performed by personnel familiar with electrical code requirements and qualified/certified for the class of work. All persons engaged in electrical work shall be instructed in accident prevention and fully informed of the hazards involved. They shall be trained in first-aid procedures that include Cardiac Pulmonary Resuscitation.

6.8.2.2. Supervisors shall ensure that no person works alone with electricity in excess of 600 volts. One person, trained to recognize the electrical hazards, shall be delegated to watch the movements of the other working personnel to warn them if they get dangerously close to live conductors or perform unsafe acts and to assist in the event of an accident.

6.8.2.3. Transformer banks or high-voltage equipment (500+ volts) shall be protected by an enclosure to prevent unauthorized access. Metallic enclosures shall be grounded. Entrances not under constant observation shall be kept locked. Signs warning of high voltage and prohibiting unauthorized entrance shall be posted at entrances and on the perimeter of the enclosure. An authorized access list of qualified personnel shall be maintained.

6.8.2.4. Where electro-static discharge (ESD) is a significant hazard to personnel or hardware, conductive floors or other methods will be used.

6.9. HAZARDOUS MATERIAL TRANSPORTATION, STORAGE, AND USE

This paragraph provides directives for protecting persons and property during the transportation, storage, and use of hazardous materials. Every effort shall be made to ensure complete safety and compliance with applicable Federal, State, and local laws and regulations. Hazardous material is defined by law as "a substance or materials in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce" (49 CFR 171.8). The Secretary of Transportation has developed a list of hazardous materials that are found in 49 CFR 172.101. At a minimum, the Federal regulations (e.g., DOT, EPA, OSHA) for transport of hazardous materials on both Federal property and public roadways shall be met. Typical hazardous materials are those that may be highly reactive, poisonous, explosive, flammable, combustible, corrosive, radioactive; produce contamination or pollution of the environment; or cause adverse health effects or unsafe conditions. For more detailed requirements, see NHS/IH-1845.3, "Hazard Communication," and NHS/IH-1845.5, "Occupational Exposure to Hazardous Chemicals in Laboratories."

6.9.1. <u>Transporting Hazardous Material</u>

6.9.1.1. NASA policy is contained in NPD 6000.1, "Transportation Management," which states that all hazardous material shall be transported by a certified contractor.

6.9.1.2. All contractor motor vehicles, rail cars, boats, and ships covered by NASA Bill of Lading and used for transportation of hazardous material shall be inspected prior to loading to ensure that the vehicle is in safe mechanical condition. The mode of transportation shall be inspected to the applicable standards of the Federal Highway Administration, U.S. Coast Guard, Department of Transportation, and Federal Railroad Administration. All vehicles transporting hazardous materials on NASA and public roadways shall display all DOT-required placards, lettering, or numbering.

6.9.1.3. Hazardous material as defined in 49 CFR 171.8 shall not be transported in NASA administrative aircraft. To ensure hazardous material is not inadvertently loaded on administrative aircraft, all cargo for shipment should be routed through the Centers transportation office or, if enroute, cargo should be accepted only from a certified shipper or freight forwarding agency.

6.9.2. <u>Storage and Use</u>.

Storage and use should comply with Federal and State regulations and address the requirements for release prevention, control, countermeasures, contingency planning, and a listing of restricted/prohibited materials for purchasing and use at Centers. Conduct inventories at least annually and assess conditions of materials in storage at least monthly.

6.10. HAZARDOUS OPERATIONS

NASA hazardous operations involve materials or equipment that have a high potential to result in loss of life, serious injury to personnel, or damage to systems, equipment, or facilities. Some examples of these are laboratory operations, high-pressure gas operations in excess of 150 pounds per square inch gage (psig), low-pressure high-volume gas operations, voltages above 600 volts, storage or handling of propellants or explosives. Other examples are the use of "heavy lift" material handling equipment, extreme temperature environments, environments with less than 19.5 percent or more than 25 percent oxygen by volume at normal atmospheric temperature and pressure, forced variations in gravity, etc.). Adequate preparation and strict adherence to operating procedures can prevent most of these mishaps. Each Center/program will provide the following actions for hazardous operations:

6.10.1. Hazardous Operating Procedure

6.10.1.1. Each Center shall identify hazardous operations and identify, assess, analyze, and develop adequate safety controls. Generally, all hazardous operations shall require Hazardous Operating Procedures (HAZOPs) or a Hazardous Operating Permit. HAZOPs consist of a detailed plan listing step-by-step functions or tasks to be performed on a system or equipment to ensure safe and efficient operations. The Hazardous Operating Permit lists special precautions, start and stop time of the operation, and the approving supervisor(s). Certain operations (e.g., rigging, high voltage, etc.) depend on adherence to overall standards and general guidelines and specific training as opposed to HAZOPs for each specific operation. In these cases, specific personnel certification requirements must be established as listed in Chapter 4. Personnel other than the certified operators shall be excluded from exposure to the operation. Where a serious degree of risk dictates, personnel shall work in pairs (buddy system).

6.10.1.2. Hazardous procedures shall be so marked conspicuously on the title page to alert operators that strict adherence to the procedural steps and safety and health precautions contained therein is required to ensure the safety and health of personnel and equipment.

6.10.1.3. All HAZOPs shall have an approval signature to certify that a review has been performed by the cognizant NASA or contractor safety representative as applicable. Deviations or changes to HAZOPs also require the approval of the cognizant NASA or contractor safety office. Center Hazardous Operations Procedure (HOP) development guidelines will include the requirement that line management concur with the proposed HOP. If approved by the contractor, a copy should be forwarded to the appropriate local NASA office for informational purposes.

6.10.2. Personnel Certification.

Personnel who certify individuals to perform or control hazardous operations, or to use or transport hazardous material must ensure the individuals possess the necessary knowledge, skill, judgment, and physical ability to do the job in a safe and healthful manner. See Chapter 4 for Hazardous Operations Safety Certification.

6.11. LABORATORY HAZARDS

This paragraph provides directives for protecting persons and property in a laboratory environment. For the purposes of this document, a laboratory is a facility in which experimentation, testing, and analysis is performed on human subjects, organisms, biological and other physical materials, substances, and equipment (including bioinstrumentation). Included also are certain equipment, repair, and calibration operations, and processing of materials.

6.11.1. Design Requirements

6.11.1.1. Design of laboratories shall incorporate the requirements of the applicable State and Federal codes required for the individual Center, e.g., building, electrical, fire protection for laboratory facilities. Escape routes shall be provided, designed, and marked in accordance with the National Fire Protection Association (NFPA) 101, "Life Safety Code." Occupational safety and health considerations such as ventilation, shower stalls, and eye wash stations shall be included in the design where applicable. For facility acquisition and construction safety guidance, see Chapter 8.

6.11.1.2. Areas with significant quantities of flammable, combustible, corrosive, and toxic liquids, solids, or gases shall be protected in accordance with the applicable provisions of NFPA 45, "Fire Protection for Laboratories Using Chemicals," as modified below. Laboratories not using or fitting the above chemical classification, yet housing unique, mission-critical, or high-value research equipment, shall conform to the provisions of NTS 1740.11, "NASA Safety - Fire Protection."

6.11.1.3. Special facilities to ensure the integrity of both terrestrial environments and biological samples returned from space shall be considered in the design of the laboratory.

6.11.1.4. Additional considerations shall be the biohazards resulting from use or handling of biological materials such as infectious microorganisms, viruses, medical waste, or genetically engineered organisms. See OSHA Standard 29 CFR 1910.1030, "Bloodborne Pathogens," for additional details.

6.11.2. Chemical and Hazardous Materials.

In addition to pertinent safety requirements found elsewhere in this document, the following requirements are specifically applicable to laboratories:

6.11.2.1. All laboratories shall be operated in accordance with chemical hygiene plans as required by 29 CFR 1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories;" NHS/IH-1845.3, “Hazard Communications;” and NHS/IH-1845.5 “Occupational Exposure to Hazardous Chemicals in Laboratories.”

6.11.2.2. Suitable facilities for quick drenching or flushing of the eyes and body of any person exposed to injurious corrosive materials shall be provided within the work area for immediate emergency use. Access to these facilities must be kept clear.

6.12.3. Mechanical

Only qualified/certified personnel shall operate machines. Machine shop safety and practice shall comply with OSHA Regulations 29 CFR 1910 Subpart O, "Machinery and Machine Guarding."

6.12.4. Solar Simulators.

All personnel shall wear skin and eye protection while in direct view of a bare pressurized arc lamp, whether energized or not, unless the system is locked out or tagged out for maintenance or repair.

6.12.5. Ventilation.

Assuring proper ventilation is primarily an Occupational Health responsibility. See NPD 1800.2, "NASA Occupational Health Program."

6.12.6. Glassware.

Because some laboratory operations use a considerable amount of glassware and ceramics, necessary safeguards shall be employed to minimize personnel injury. Refer to the “Guide for Safety in the Chemical Laboratory,” Manufacturing Chemists' Association, Inc., and “Handling Glassware."

6.13. LIFTING SAFETY

NASA requirements for protecting persons and property during lifting operations are mandated in NASA-STD 8719.9 (formerly NSS 1740.9), "NASA Lifting Devices and Equipment Manual." The standard establishes minimum safety requirements for the design, testing, inspection, personnel certification, maintenance, and use of overhead and gantry cranes, mobile cranes, derricks, hoists, special hoist-supported personnel lifting devices, Hydrasets, hooks, and slings for NASA-owned and NASA contractor-supplied equipment used in support of NASA operations at NASA Centers. For lifting devices and equipment not covered by NASA-STD-8719.9 (e.g., forklifts, A-frames, floor jacks, aerial buckets, etc.), it is NASA's policy to follow standard industry/manufacturer recommended practices and applicable Federal, State, and local government regulations.

6.14. EXPLOSIVE AND PROPELLANT SAFETY

NASA-STD-8719.12 (formerly NSS-1740.12), "NASA Safety Standard for Explosives, Propellants, and Pyrotechnics," provides standards for protecting persons and property from hazards of explosives and explosive materials, including all types of explosives, propellants (liquid and solid), oxidizers, and pyrotechnic. NASA-STD-8719.15, (Formerly NSS 1740.15) “Safety Standard for Oxygen and Oxygen Systems” and NASA-STD-8719.16, (Formerly NSS 1740.16) “Safety Standard for Hydrogen and Hydrogen Systems” address the requirements for working with those substances. Explosive, propellant, and pyrotechnic operations shall be conducted in a manner that exposes the minimum number of people to the smallest quantity of explosives for the shortest period consistent with the operation being conducted.

6.15. UNDERWATER OPERATIONS SAFETY

NASA-STD-8719.10, (formerly NSS 1740.10), "Underwater Facility and Non-open Water Operations," shall be used as the minimum standard to establish the safety requirements for all NASA neutral buoyancy facilities, equipment, personnel, and operations involving underwater activities that provide simulation of a weightless environment. This standard also applies to NASA personnel participating in underwater operations non-NASA facilities.

6.16. LAUNCH VEHICLE AND SPACECRAFT OPERATIONS SAFETY

This paragraph provides policy and requirements for minimizing the risk to the public, operations personnel (including flight crews), public property, and Government property during launch vehicle (missile) and spacecraft launch and flight operations. It also covers the subjects of NASA Headquarters Safety representatives, Range Safety, Spacecraft Safety, and Space Debris Safety.

6.16.1. <u>NASA Headquarters Safety Representatives</u>.

A NASA Headquarters-designated safety representative supports each launch of a NASA-managed launch vehicle, including orbital, manned/unmanned; major sub-orbital; and other vehicles as determined by the AA/OSMA. These representatives monitor the preparations of each NASA launch vehicle and NASA payload for flight, evaluate the readiness of the vehicle and payload, and provide the appropriate NASA manager a concurrence or non-concurrence on the readiness of the vehicle and payload to begin launch and flight operations. The representatives are assigned a position on the launch operations communications network and are responsible for determining the NASA Headquarters

Safety concurrence with the readiness for launch and communicating that status to the appropriate person on the network.

6.16.2. Range Safety.

This subparagraph provides requirements for Range Safety, which includes launches for which there is a NASA involvement. It includes, but is not limited to, launches from a NASA range, using a NASA payload, a NASA-contracted launch vehicle, or NASA funds, or involving NASA on an advisory basis.

6.16.2.1. National Ranges

- NASA space launches are conducted from three national ranges: the Eastern Test Range (ETR) and Western Test Range (WTR) operated by the DOD, and the Wallops Flight Facility (WFF) operated by NASA.

- Policy, requirements, and procedures to ensure the safety of personnel, facilities, and equipment placed at risk during operations on these ranges are delineated in the following range safety requirements documents:

    - Eastern and Western Test Range Regulation (EWR) 127-1, "Range Safety Requirements,"

    - Kennedy Handbook (KHB) 1700.7, "STS Payload Ground Safety Handbook," for Shuttle Payloads; and

    - Goddard Procedures Guidebook (GPG) 1771.1, "Range Safety," for WFF."

- The responsibilities of ESMC and NASA for launches from the Kennedy Space Center are defined in a Joint Operating Support Agreement.

- This agreement assigns responsibility for all in-flight safety to ESMC, ground safety at Cape Canaveral Air Force Station to ESMC, and Kennedy Space Center ground safety to NASA. Vandenberg Air Force Base, the host base for Western Test Range (WTR), is responsible for all missile and ground safety.

- NASA aircraft and other test operations may be conducted at the Eastern Test Range (ETR), WTR, or other national ranges such as White Sands Missile Range (WSMR), Wallops Flight Facility (WFF), Air Force Flight Test Center (AFFTC), and Eglin Test Range. For these ranges, the applicable policy, requirements, and procedures of the host range shall be followed.

- Launches conducted at non-NASA ranges shall comply with that range's policies; however, the criteria of this section shall be considered the minimum requirements for safe operations by range users, NASA personnel, and NASA contractors. When range requirements conflict, the most stringent requirement shall dominate.

6.16.2.2. Centers

- The Center responsible for coordinating the NASA participation in the launch operation shall ensure conduct of a coordinated range safety effort. The Center also ensures that the hazards associated with the launch of space vehicles and test articles in which NASA has a direct interest or involvement are eliminated or minimized. This includes all safety activities from design through test, launch, vehicle flight, and recovery.

- The Center will ensure the user submits a comprehensive Safety Data Package prior to approval for payload processing and launch. Users will submit these safety packages to the appropriate Range Safety Office (RSO), NASA Headquarters Safety and Risk Management Division, NASA (Sponsor) Centers, and the Launch Vehicle Program.

- Centers shall comply with established national range policy, requirements, and procedures.

- Centers shall ensure the safety of NASA personnel and resources and minimize risks to the public (personnel and property).

6.16.2.3. Commercial Launch Operations.

For commercial ventures funded by NASA or with a NASA payload, the launch contractors will ensure a proper safety program is conducted. NASA representatives will oversee the vehicle preparation, payload integration, and launch operations as outlined in the NASA Headquarters commercial launch vehicle policy.

6.16.2.4. Range Safety Officer.

Each Center responsible for a launching range will designate a Range Safety Officer. The Range Safety Officer shall protect the general public and public property from harm or damage resulting from the debris or impact of hazardous components from an errant vehicle (stage) or catastrophic flight. Additionally, the Officer shall use and certify the operation and maintenance of the Range Safety System that is comprised of a range safety display system, range clearance capability, radar, optic and telemetry tracking, and display systems, and may include command control capability for a flight termination system. Although the risk associated with space-vehicle launches can never be eliminated completely, the Range Safety function is to minimize risk while not unduly restricting the probability of mission success.

6.16.2.5. Development and Operations Planning

- To reduce costly safety engineering changes to aerospace systems for operation at any range, Range Safety personnel shall be involved in the early concept stage of development and operations planning.

- The appropriate Center shall notify NASA Headquarters and the designated Range Safety organization of all Preliminary Design Reviews (PDR's) and Critical Design Reviews (CDR's). The NASA Headquarters designated safety representative and Range Safety personnel should attend PDR's and CDR's which involve safety-critical systems or operations. Each Program Manager must ensure adequate funding is available to support this requirement.

6.16.2.6. Readiness Reviews and Audits.

Each Program that uses a range shall provide documentation for range safety reviews. The documentation shall include vehicle and payload descriptions, range requirement and compliance documents [Accident Risk Assessment Report (ARAR) and Missile Systems Prelaunch Safety Package (MSPSP)], flight plan, missile system prelaunch operation plan, descriptions of flight termination system, descriptions of radionuclide, and any range safety waiver requests. Submittal of all documentation shall allow sufficient lead-time for a complete review prior to launch. The Balloon and Sounding Rocket program is not included in the NASA Headquarters review unless specific requests for information are requested.

6.16.2.7. Mishap Reporting and Investigation.

To ensure proper mishap investigation, each program or project office shall complete a pre-mishap contingency plan two weeks prior to launch. For policy see NPD 8621.1G “Mishap Reporting and Investigating Policy.”

6.16.3. <u>Space Debris Safety</u>.

The NASA safety policy for space debris is contained in NPD 8710.3, "NASA Policy for Limiting Orbital Debris Generation." This policy requires each program involved in spacecraft launch and/or deployment to formally assess and minimize the potential for generation of orbital debris. NASA-STD 8719.14 (formerly NSS 1740.14), “Guidelines and Assessment Procedures for Limiting Orbital Debris,” may be used for both the preliminary and final assessment.

6.17. TEST OPERATIONS SAFETY

This paragraph provides direction for protecting persons and property during test operations, both manned and unmanned. Testing also includes hazardous training activities and demonstrations of test hardware or procedures. The requirements stated herein apply to test facilities; test equipment located within, or attached to, test facilities; equipment being tested; test personnel; test conduct; and test documents. Additional requirements are detailed in Chapters 1 and 3 and in other paragraphs of this chapter.

6.17.1. Test Plans

Test plans shall be evaluated to ensure test performance within safe operating limits. Evaluations will address the test article, test facility, operator involvement, test conditions, potential risk to adjoining facilities and personnel, etc.

6.17.2. Safety Documentation

Safety documentation establishes the basis for safe test conduct by means of engineering analyses (including hazard analyses calculations). Established test controls will be clearly identified in test drawings, facility drawings, test procedures, etc. The level of safety documentation required will be tailored to the risks involved with the test.

6.17.3. Test System Requirements. Personnel responsible for developing test systems must do the following:

6.17.3.1. Design test systems such that test personnel or critical test hardware are not subjected to a test environment wherein a credible single-point failure (e.g., power loss) could result in injury or loss to the critical test hardware.

6.17.3.2. Construct all systems (electrical, mechanical, pneumatic, and/or hydraulic) so that no single failure could cause a critical condition.

6.17.3.3. Ensure that software that may interface with test systems meets the requirements stated in Chapter 3. Software by itself is not hazardous; however, when interfaced with test hardware, software could command a hazardous condition in the hardware.

6.17.3.4. Calibrate and certify safety-critical instrumentation before test operations and as required by test documentation or the test organization's internal procedures.

6.17.3.5. Ensure all personnel involved in tests are informed of potential hazards, safety procedures, and protective measures.

6.17.3.6. Ensure the availability of appropriate emergency medical treatment facilities.

6.17.3.7. Conduct formal reviews of those engineering designs that are complicated or potentially hazardous to facilities.

6.17.3.8. Ensure test reports include anomalies, safety implications, and lessons learned.

6.17.4 Test Readiness Review.

Test Readiness Reviews must be conducted for tests involving new or modified hardware and/or procedures. These reviews shall determine the safety, technical, and operational readiness of the test.

6.17.5. Pre-test Meeting.

A pre-test meeting must be conducted with all involved personnel to discuss the research facility, design, instrumentation, safety, and operator training and certification. The meeting should also establish the test plan, identify test constraints to ensure facility safety, and determine test article readiness.

6.17.6. Human Research Subjects.

The requirements for the protection of human research subjects are contained in NPD 7100.8B, "Protection of Human Research Subjects," and 45 CFR 46, "Protection of Human Subjects."

6.17.1. Human Test Subject Requirements.

In addition to the requirements regarding confined spaces cited in paragraph 6.19., crewed test systems shall meet the following criteria:

6.17.1.1. Tests involving hazardous substances, where human test subjects or test team personnel may be exposed, will be reviewed for adequacy of test team safeguards.

6.17.1.2. For tests requiring crew participation in a pressure suit, a facility environmental control system failure or failure in the distribution system affecting one pressure-suited occupant shall not affect any other pressure-suited occupant.

6.17.1.3. A means shall exist of immediately detecting an incipient fire or other hazardous condition in each crew compartment of any test area. Automatic detection shall be provided for critical areas not suitable for visual monitoring.

6.17.1.4. Crewed test systems shall be designed for timely and unencumbered rescue of incapacitated test subjects.

6.17.1.5. Software controlling crewed test systems shall be thoroughly analyzed to ensure that no command could result in death or injury to the test subjects.

6.17.1.6. Crewed test systems shall be designed to provide for manual overrides of critical software commands to ensure the safety of test subjects during any system event or test scenario (normal operation, malfunction, emergency, etc.). Such overrides shall support safe test termination and egress of test subjects as appropriate.

6.17.1.7. Medical resources and facilities needed for response will be alerted, on-call, and immediately available as needed.

6.18. NON-IONIZING RADIATION

Microwave and radar protection standards are covered in various State regulations, national consensus, and Federal standards including 29 CFR 1910.97. This paragraph provides directives for protecting persons and property during laser use in NASA operations. The primary laser hazard to humans is eye and/or skin damage from direct exposure to the beam or specula reflection, and in some cases, viewing the diffuse reflection. Laser operations during any open-air laser scenario conducted on Department of Defense (DOD) controlled ranges or test facilities or by DOD personnel will use Document 316-91, "Laser Range Safety," for guidance.

6.18.1. Requirements

6.18.1.1. 21 CFR 1040 states that people shall not be exposed to laser radiation in excess of the maximum permissible limits. The array of possible physical controls is discussed in 21 CFR, State regulations, and ANSI standards.

6.18.1.2. NASA procedures and requirements are:

- Prevent exposure of personnel to laser radiation exceeding the permissible exposure levels.

- Ensure to the maximum extent practical, hazards to personnel are eliminated, or procedures are developed and equipment provided for those hazards that cannot be eliminated by engineering design. This must occur before laser systems become operational.

- Procure or manufacture only laser products that comply with the performance standards of 21 CFR's 1040.10 and 1040.11, unless a specific exemption is obtained from the U.S. Department of Health and Human Services, Food and Drug Administration (FDA).

- Ensure that laser operation conforms to the principles and requirements set forth in ANSI Z136.1, "American National Standard for Safe Use of Laser" and ANSI Z136.2, "Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources."

- Ensure that any laser that can cause injury or damage has a Center-approved safety permit, test plan, or test procedure review.

- Where a planned laser operation has the potential of the beam striking an orbiting craft, the Program Manager or designated Laser Radiation Safety Officer shall contact the Laser Safety Clearing House to obtain a "Site Window" clearance. The clearance is obtained from the Orbital Safety Officer, U.S. Space Command/J3SOO, 1 NORAD Road, Suite 9-101, Cheyenne Mountain AFB, CO 80914-6020, Stop 4, Phone: (719) 575-3510.

- A qualified Laser Radiation Safety Officer shall review procedures for all tests that use lasers. An individual designated/approved by the Center Safety organization will be on site to monitor all laser tests.

6.18.2. Ground Operations Using Class III-B and IV Lasers.

During ground operations using Class III-B and IV lasers, users shall:

6.18.2.1. Operate Class III-B and IV lasers only in controlled environments or designated areas that have no unintended reflective or transmitting surfaces.

6.18.2.2. Post the laser operations area with standard warning placards as set forth in ANSI Z136.1. and ensure the area is isolated to prevent inadvertent entry.

6.18.2.3. Require laser goggles or other approved methods of eye protection in accordance with requirements of ANSI Z136.1.

6.18.2.4. Keep all flammable materials/vapors away from any laser during operation unless specifically authorized by the operation/test plan.

6.18.3. Airborne Operations Using Class III-B and IV Lasers:

6.18.3.1. Programs Managers must identify use of Class III-B and IV lasers early in the system acquisition process and track their use during the program life cycle. A realistic application of safety engineering to laser systems can avoid or reduce the costs involved in redesign, time lost in modification, and loss of mission capability. Program managers and safety evaluators shall assess the safety aspects, compliance with safety requirements, and resolution of laser safety-related problems.

6.18.3.2. Design of laser systems for NASA aircraft and spacecraft shall include a system of interlocks to prevent inadvertent laser output. When a test circuit switch is provided to override the ground interlock to aid ground test operations, maintenance, or service, design must preclude inadvertent operation.

6.18.3.3. The crew shall not operate the laser except in accordance with the prescribed mission profile. The craft commander shall ensure that the laser system is used in accordance with the test plan.

6.18.3.4. For long-range laser shots, Program Managers shall designate as large a exclusion area as practical to minimize the risk to the people outside the area. A buffer area should be added around the exclusion area. Air Force AFOSH Standard 161-10, "Health Hazard Control for Laser Operations," includes a guide for operation of lasers from aircraft. It can be used to develop the buffer zone for space-based laser shots directed at the ground. (See Range Commanders Council (RCC) Document 316-91, "Laser Range Safety.”)

6.18.3.5. Program Managers shall ensure a hazard evaluation and written safety precautions are completed prior to airborne laser operations. Hazard analysis shall consider catastrophic events and the need for very reliable, high-speed laser shutdown should such events occur. (See ANSI Z136.1 for hazard evaluation and control information.)

6.18.3.6. Qualified personnel shall perform laser hazard evaluations to determine specific hazards associated with specific uses, establish appropriate hazard control measures, and identify crew and public-at-large protection requirements.

6.18.3.7. When completing the hazard evaluation, the Program Manager shall consider and document the atmospheric effects of laser beam propagation, the transmission of laser radiation through intervening materials, the use of optical viewing aids, and resultant hazards, e.g., electrical, cryogenic, toxic vapors.

6.18.4. Software

6.18.4.1. Software shall provide safety precautions for fast-moving lasers and prevent misdirected laser operation.

6.18.4.2. Laser software development shall be subjected to a software safety analysis per Chapter 3. Existing systems are exempt but shall be reviewed to ensure the provision of safety precautions.

6.18.5. Training.

Only trained and certified employees shall be assigned to install, adjust, and operate laser equipment. Personnel operating lasers shall be trained and certified in accordance with Chapter 4 of this manual.

6.19. CONFINED SPACES

The following provide the safety and health requirements for entry into confined spaces:

6.19.1. NASA Health Standard (NHS)/IH-1845.2, "Entry Into and Work in Confined Spaces."

6.19.2. OSHA 29 CFR 1910.146, "Permit Required Confined Spaces."

6.19.3. American National Standards Institute (ANSI) Z117.1, "Safety Requirements for Confined Space."

6.19.4. NIOSH Publication No. 87-113, "A Guide to Safety in Confined Spaces."

CHAPTER 7: AVIATION SAFETY

7.1. PURPOSE

This chapter provides the basic requirements of the NASA Aviation Safety Program and provides guidance for managers and Aviation Safety personnel to establish/implement their aviation mishap prevention programs. NASA philosophy is that mishaps are preventable and that mishap prevention is an inherent function of leadership and management. NASA's major involvement in aeronautics dictates a commitment to aviation safety, under not only the Aviation Safety Program but also technology programs as well. NASA ensures aviation safety through a comprehensive and proactive program covering all aspects of flight.

7.2. AVIATION SAFETY PROGRAM

7.2.1. The NASA Aviation Safety Program requires aviation safety measures to be in effect at each level of aviation management. Under this concept, the Director/Aviation Manager responsible for aviation safety and risk management at each level is assisted by an Aviation Safety Officer (ASO)/manager who is an integral part of the Aviation Manager's staff and not part of a separate safety organization. The program is supported by system safety personnel as required. Headquarters safety personnel will conduct reviews and staff visits to provide process verification, insight, and monitoring of management's effectiveness in aviation safety. Headquarters safety personnel will also provide technical and operational assistance to improve the overall safety program.

7.2.2. The highly diversified aviation activities within NASA require a tailored Aviation Safety Program for Headquarters and each flight activity. The primary responsibility for each Center's Aviation Safety Program rests firmly with the Center Director. The Associate Administrator for Management Systems and Facilities is responsible for NASA Headquarters aviation operations. Aviation safety programs shall follow the applicable guidelines for each respective flight activity set forth in this chapter; NPG 7900.3 (V1), "Aircraft Operations Management Manual;" and NPG 7900.3 (V2), "Mission Management Aircraft Operations Manual."

7.3. PROGRAM RESPONSIBILITIES AND REQUIREMENTS

The NASA Aviation Safety Program is Agency-wide, covering several Headquarters Offices and all Centers. To ensure effective implementation, an Aviation Safety Program shall conform to the organization's aviation management structure.

7.3.1. <u>The NASA Administrator</u> is the senior person responsible for Agency-wide aviation safety.

7.3.2. <u>The AA/OSMA</u> has been delegated the authority to establish NASA Aviation Safety Program requirements and provide support and independent oversight of NASA aviation safety. The AA/OSMA shall provide the NASA Administrator an independent assessment of NASA's aviation safety status and provide immediate information on critical safety issues.

7.3.3. The Director, Safety and Risk Management Division (Code QS), designates the NASA Aviation Safety Officer (ASO). The NASA ASO provides overall aviation safety oversight and management support for aviation safety. Through this independent oversight function, the ASO shall ensure that Aviation Safety Program requirements are applied at the appropriate levels of responsibility throughout NASA.

7.3.4. NASA ASO, shall:

7.3.4.1. Serve as the independent Agency focal point for NASA aircraft safety issues.

7.3.4.2. Provide systems safety oversight to ensure Headquarters and Center aircraft operations comply with NASA safety policy.

7.3.4.3. Coordinate all OSMA requirements affecting aviation safety or reporting.

7.3.4. 4. Ensure there is an effective Agency mishap and incident reporting and corrective action system.

7.3.4.5. Identify aviation safety issues through mishap investigation and analysis.

7.3.4.6. Serve as ex-officio board member or provide a designee to major aircraft mishap investigations and provide independent oversight and expert guidance in investigation procedures and techniques.

7.3.4.7. Participate in the annual NASA ASO meeting.

7.3.4.8. Monitor and promote Agency-wide awareness of and motivation for the Aviation Safety Program.

7.3.4.9. Attend selected program Flight Readiness and Safety Reviews.

7.3.4.10. Serve as an advisor to the Intercenter Aircraft Operations Panel (IAOP) and participate in IAOP activities, including meetings, reviews, and subpanel activities.

7.3.4.11. Develop the NASA Aviation Safety Reference Guide (QS-ASO-92-001) and ensure it is current and meets the needs of NASA.

7.3.4.12. Monitor and act on the aviation safety needs of the Headquarters Enterprise and Program Offices, Aircraft Management Office (AMO), IAOP and its subpanels, and Centers.

7.3.4.13. Interface with other safety organizations.

7.3.4.14. Advocate aviation safety research.

7.3.4.15. Conduct aviation safety staff visits and reviews.

7.3.4.16. Coordinate recommendations from mishap investigations that require corrective action from sources or agencies outside of NASA.

7.3.4.17. Participate in selected aircraft flight operations.

7.3.5. The AA for Management Systems and Facilities, in accordance with NPD 7900.3 (V1), is responsible for policies and other matters related to NASA aircraft management. This includes developing guidelines for safe aircraft operations and implementing an Agency-wide Aviation Safety Program in accordance with Agency policies.

7.3.6. NASA Headquarters Enterprise Associate Administrators and Institutional Program Officers have line management responsibility for aviation safety for their respective Centers/flight operations. This requires ensuring implementation of aviation safety programs for their Centers, allocating aviation resources to meet objectives/programs safely, promulgating safety awareness, conducting mishap investigations, and developing/implementing corrective action.

7.3.6.1. A senior, single point of contact for aviation safety and aviation management shall be designated within these offices to provide liaison with the OSMA and the Office of Management Systems and Facilities.

7.3.6.2. Except for NASA aircraft operations that are the function of the Office of Management Systems and Facilities, the Associate Administrator for Aeronautics and Space Transportation Technology manages aviation safety-related technology and research programs.

7.3.7. The Aerospace Safety Advisory Panel (ASAP)

The ASAP was established as an advisory committee to NASA by Section 6 of the NASA Authorization Act, 1968 (PL 90-67, codified as 42 U.S.C. 2477). The ASAP reviews and evaluates program activities, systems, procedures, and management policies and provides assessment of these areas to NASA management and Congress. It is in this role that the ASAP provides independent advice on NASA aviation safety-related issues to the AA/OSMA and to the Administrator.

7.3.8. The Center Director is the primary NASA official responsible for ensuring the safe operation of all aircraft assigned to the Center, and for establishing and implementing an Aviation Safety Program tailored to their aircraft/airfield operations. Center Directors accomplish these tasks by compliance with NASA Headquarters directives and their own directives. They are assisted by NASA Headquarters staff visits and the reports and recommendations of the IAOP and ASAP.

7.3.9. Center Aviation Manager of Flight Operations is the senior line person assigned aircraft operations responsibilities. The manager depends on the local ASO to identify mishap potential and assist in administering the Mishap Prevention Program. However, the manager cannot delegate the line responsibility for the prevention of mishaps. A manager's experience, leadership, and philosophy are decisive factors in ensuring safe operations. Aviation Managers of Flight Operations shall ensure the following:

7.3.9.1. Flight rules, regulations, and other advisory material required for safe flight operations are obtained/published and updated, and all personnel understand and comply with them. Where local conditions or special mission requirements dictate, special rules/procedures should be established and followed.

7.3.9.2. Restrictions to flight, Notice to Airmen (NOTAM), Weather (WX), and other pertinent information are readily available prior to initiation of flight operations. Aviation Managers should not waive any safety requirements set by regulations, NPD's, or other authoritative sources, unless the risk is accepted. In these cases, managers should justify and document their actions in writing, with approval of the Center Director and appropriate Headquarters officials.

7.3.9.3. A crew rest policy is in effect.

7.3.9.4. Functional and effective Foreign Object Damage (FOD) prevention and tool control programs are in effect.

7.3.9.5. Aerial demonstrations involving NASA aircraft, if conducted, encompass the Center top management's approval to include flight routines, pilot assignment, training prerequisites, and weather limits.

7.3.10. Center Aviation Safety Officer.

Although the ASO's perform primarily pilot duties at most Centers, the ASO position should be a full-time responsibility. Because the ASO serves as the manager's focal point for aviation safety matters, this individual should report directly to the senior aviation manager responsible for risk management. The ASO also acts in behalf of the Center Director when discharging this responsibility. The ASO shall foster aviation safety measures and use all resources available to promote mishap prevention. ASO selection should be based on education, experience, and ability. Ideally, this individual should be on flight status, be current in assigned aircraft, be graduate of an approved aviation safety course, and have experience in aircraft mishap investigation. To accomplish these tasks, the ASO should refer to the NASA Aviation Safety Reference Guide to ensure appropriate elements are contained in the Center's aircraft Mishap Prevention Program.

7.3.11. Pilot-In-Command

7.3.11.1. The NASA aircraft Pilot-In-Command (PIC) is responsible at all times for the safe operation of the aircraft and the safety of the passengers. The PIC is the final authority as to whether a flight shall be delayed or diverted for reasons of weather, aircraft conditions, or other safety-related considerations.

7.3.11.2. The PIC shall ensure that passenger briefings are conducted and include pertinent egress, safety, and emergency information.

7.3.12. Individual Responsibilities.

All personnel, including contract personnel associated with NASA flight operations, shall conduct aviation-related activities in a safe and responsible manner and in compliance with NASA aviation guidelines and safety programs. Contracts involving or affecting aviation operations shall stipulate compliance with aviation safety requirements. Aviation safety is a personal responsibility of every person involved in aviation-related activities.

7.4. AVIATION SAFETY PROGRAM ELEMENTS

This paragraph discusses the general elements of an effective Aviation Safety Program. Each Center shall implement an aircraft Mishap Prevention Program that includes the elements appropriate for their operation. Detailed elements are contained in the NASA Aviation Safety Reference Guide.

7.4.1. Aircraft Mishap Prevention Survey/Review.

A NASA Headquarters aviation safety review of each Center is required biennially. The IAOP, with the assistance of the AMO, conducts these formal reviews with independent safety oversight by the NASA Headquarters Safety and Risk Management Division. Centers should conduct internal surveys during the alternate year. These reviews provide an objective evaluation of aircraft operations, maintenance, crew procedures, and facilities to ensure safe and efficient operation and aircraft usage consistent with assigned goals and Center requirements.

7.4.2. The Aviation Safety Reporting System

7.4.2.1. A major program jointly sponsored with the Federal Aviation Administration (FAA) is the NASA Aviation Safety Reporting System (ASRS). This program is designed to identify and publicize deficiencies/discrepancies that have potential safety impact on the aviation community. The program does not address mishap reports but rather solicits reports of perceived safety hazards through a system of protected reporting. This system receives, stores, and distributes pertinent data. It also analyzes the data, conducts special studies, and reports on the results.

7.4.2.2. The Office of Management and Budget (OMB) Report Control Number for the ASRS is 04-R-9206, which has been assigned to Ames Research Center Form 77.

7.4.2.3. All ASOs shall use the services of the ASRS program, support its objectives, and integrate the program's output into their local aviation safety program. They shall encourage pilots and other members of the aviation community to submit timely reports of hazardous conditions or incidents as prescribed under the ASRS program.

7.4.3. Aircraft Mishap Reporting and Investigation.

The principle of mishap reporting, investigation, identification of root causes, and corrective action is central to an effective aviation safety program and shall be conducted in accordance with the current NPD 8621.G, "NASA Mishap Reporting and Investigating Policy," and NPG 8621.xx, "Procedures and Guidelines for Mishap Reporting, Investigating, and Recordkeeping." Close call reporting, investigation, and dissemination of lessons learned is an essential element of mishap prevention.

7.4.4. Incentives and Awards.

All aviation personnel desire both satisfaction and recognition for their achievements. Safe behavior should be recognized and rewarded. Properly used, incentives and awards can be extremely effective in both motivating and maintaining safe behavior. Further information on awards is located in Chapter 1 and Appendix C.

7.4.5. Occupational Health, Medical Clearance, Emergency Egress, and Survival.

Close coordination with occupational health and medical officers and aviation personal equipment specialists shall be maintained. This enhances protection of aircrew and passengers by ensuring proper medical clearances for flight duties, adequate training, and properly maintained and functioning emergency survival equipment. The proper care and use of parachutes, egress systems, breathing equipment, protective equipment, and survival gear are subjects for safety surveillance. The aviation medical program and aviation life support equipment are important components of this safety program element.

7.4.5.1. The Aviation Medical Program. The objectives of the Aviation Medical Program are to promote aviation safety and prevent illness and injury of aviators and aviation support personnel. Specific aims are to promote the health and safety of aviation personnel through appropriate preventive medicine practices; ensure a safe, toxic-free environment for aviation personnel; and evaluate personal equipment and the man/machine interface for toxic and hazardous conditions. Managers shall ensure establishment and support of an aviation medicine program tailored to specific needs of aviation personnel supported.

7.4.5.2. Aviation Life Support Equipment. Aviation Life Support Equipment (ALSE) is a vital link to a comprehensive aviation safety program. The responsibility, accountability, inspection, and maintenance of this equipment should be delegated to support personnel who are familiar with the equipment, experienced and knowledgeable in aviation concept, and aware of the need for ALSE. ALSE school attendance is desirable and encouraged.

7.4.6. Facilities and Equipment.

Adequate flight facilities shall be established, maintained, and inspected. These include airfield, aircrew, maintenance, aircraft service life extension facilities, Crash Fire Rescue (CFR) facilities and emergency facilities and equipment for off-site operations.

7.4.7. Cargo Safety.

Provisions shall be made for the safe handling and stowing of cargo, including hazardous materials, in NASA aircraft. Additionally, contract carriers and airlift services used by NASA are required to abide by sound safety practices and Department of Transportation (DOT) regulations, including 29 CFR 175, "Carriage by Aircraft," in the transportation of hazardous materials and cargo. Mixed cargo and passenger loads shall be monitored for safe practices.

7.4.8. Dissemination of Aviation Safety-Related Information and Material.

The best aviation safety material contributes very little to safety programs unless it is read or used by the people who are part of the Aviation Safety Program. Aviation Safety Managers should ensure that these materials are distributed throughout their Centers and other sites. Safety information that would be of interest Agency wide should be sent to NASA Headquarters Safety and Risk Management Division for distribution. This information may assist in saving lives and preserving valuable resources.

7.4.9. Aviation Safety Reference Guide.

Additional information on aviation safety is contained in the "Aviation Safety Reference Guide," QS-ASO-92-001.

7.5. INTERFACES WITH OTHER AGENCIES

NASA aviation activities interface with the aircraft industry, DOT/Federal Aviation Administration (FAA), the Department of Defense (DOD), and foreign governments. These resources shall be used fully in aviation safety matters. Centers shall have a process in place with outside organizations to exchange flight information that effects their assigned aircraft.

7.5.1. Interagency Committee for Aviation Policy (ICAP).

The ICAP was established by GSA Order ADM 5420.99, dated August 9, 1989, as directed by revised OMB Circular A-126, issued January 18, 1989. The committee's goal is to coordinate Government-wide improvements in efficiency, effectiveness, economy, and safety of Federal executive agency public aircraft activities. NASA is represented on the executive committee by one primary and one alternate representative from the Office of Management Systems and Facilities, and by representatives from both The Office of Management Systems and Facilities and OSMA on the following subcommittees: Regulatory Policy; Safety, Standards, and Training; and Data Management Systems. The NASA representatives will keep the NASA aviation community apprised of deliberations and actions forthcoming from the committee

7.5.2. Department of Transportation.

NASA Aviation Safety has a direct interest in FAA flight services and facilities used by NASA aircraft. These include departure, enroute, and arrival procedures, and the airways, restricted airspace, and local flying/training areas. Cooperation with FAA at the local level should foster a mutual understanding in developing safe aviation control procedures. Research and development (R&D) activities present opportunities for NASA/FAA cooperation to enhance safety.

7.5.3. Department of Defense.

Because NASA uses many military airfields and aircraft common to the military services, coordination with the Army, Navy, and Air Force is required. Use of the various Service safety publications, cross-exchange of accident prevention data, and participation in joint safety efforts are also required. Safety and accident investigation provisions must be included in joint agreements with DOD agencies for joint use or loan of aircraft.

7.5.4. Industry.

Although this interface is normally through the contracting officer, special safety provisions in contracts shall require exchange of accident information concerning the types of aircraft involved. Safety personnel shall participate in design reviews and inspections during the acquisition phase to ensure proper safety coverage.

7.5.5. Foreign Governments.

Most foreign interface occurs during joint research or exchange programs and aviation shows/displays. Aviation safety is keyed to saving lives and property and should not have political or national boundaries. The NASA aviation safety program shall have provisions for such exchanges.

CHAPTER 8: FACILITY SAFETY

8.1. PURPOSE

This chapter establishes safety procedures and guidelines to enhance the safety and mission success aspect of NASA's facility acquisition, construction, and activation process. Specific safety tasks to be accomplished to ensure safety during construction, operation, maintenance, and final disposition of the facility will be documented in the Safety Management Plan (SMP), which will be included in the Facility Project Management Plan in accordance with NPG 8820.2. The SMP for each facility acquisition should be tailored to include those tasks appropriate considering the size and complexity of the project and associated safety risks. NASA-STD 8719.7 provides a review of the facility life cycle and the safety tasks that shall be accomplished (as applicable) during a facility acquisition project life cycle.

8.2. APPLICABILITY AND SCOPE

This chapter is not a direct instruction to NASA contractors who provide planning, Architect-Engineering (A-E) design, or construction contract services. It is guidance to the responsible NASA Center program/project management, contracting office, safety assurance, and fire protection organization personnel who implement the safety programs essential to meeting each facility acquisition and construction work package effort in accordance with NPG 7320.1 and NPG 8820.2. This chapter shall be applied to Construction of Facilities (CoF) projects including discrete programs (restoration/ modernization, new capability), minor programs (repair, rehabilitation/modernization, minor construction) facilities maintenance projects, and environmental compliance and restoration projects. This chapter shall also be applied to Center approved projects according to the degree of impact of safety policy and regulatory considerations on those projects. This document shall not supersede more stringent requirements imposed by individual NASA organizations and other Government agencies.

8.3. OBJECTIVES

NASA's facility acquisition safety and construction safety objectives are to:

8.3.1. Identify, track, and resolve hazards at the earliest possible phase to minimize the cost and need for a retrofit program.

8.3.2. Perform safety oversight functions to ensure compliance with NASA safety policies.

8.3.3. Provide for review of all proposed projects to ensure that all safety requirements are specified and funds are adequately allocated.

8.3.4. Provide the necessary technical reviews that include safety aspects of all facility acquisition and construction efforts to ensure that they are being conducted in accordance with sound safety engineering principles.

8.3.5. Monitor facility construction, modification, repair, and rehabilitation for compliance with appropriate safety, fire protection, and building codes and standards. NASA fire protection and safety personnel shall monitor the compliance effort in the various phases of the projects. For projects with safety or fire protection implications, this effort will be formal, with the safety office/fire protection office providing a formal sign-off.

8.3.6. Ensure that any final inspection effort (Operational Readiness Inspection (ORI), Operational Readiness Review (ORR), Test Readiness Review (TRR), Pre-Final Inspection (PFI), Final Inspection (FI), etc.) includes a safety and/or health representative as appropriate and that all facility safety and health issues are documented, resolved, or adequately controlled prior to acceptance and/or activation.

8.4. SAFETY GUIDANCE

To achieve facility acquisition, construction, and activation of safety assurance objectives, NASA will:

8.4.1. Designate and assign facility safety program responsibilities to a NASA Center Safety and Mission Assurance organization that is independent from the specific facility (user) management.

8.4.2. Assure, regardless of the source or amount of funds, that the fire protection and safety organizations review all proposed NASA-owned, controlled, or operated facility configuration changes and construction work change orders that have a potential safety impact. This does not preclude the use of checklists and other guidelines to assist the project in determining the potential safety or fire impact.

8.4.3. Incorporate safety criteria or requirements into the facility project design, construction work bid packages, and the facility operation and maintenance instructions in accordance with NPG 7320.1, "Facilities Engineering Handbook," and NPG 8820.2, "Facility Project Implementation Handbook."

8.4.4. Mandate compliance with NASA supplementary and alternate NASA Technical Standards for safety that may apply for all NASA-managed construction work. For construction undertaken at NASA by the U.S. Army Corps of Engineers, compliance with EM 385-1-1, "U.S. Army Corps of Engineers, Safety and Health Requirements," is mandatory. For related NASA-managed projects, EM 385-1-1 will be considered as an advisory document.

8.4.5. Ensure facility operation and maintenance instructions and changes are developed by the Center based on the facility mission and operational requirements. All procedures shall include sufficient detail to identify residual hazards and cautions to NASA personnel. Deviation or changes to Hazardous Operating Procedures (HAZOP's) require the approval of the cognizant NASA/contractor safety or health offices. Those procedures and instructions identified as hazardous shall require fire protection and safety office approval as provided in Chapter 6.

8.5. FACILITY MANAGERS

The Center Director or designee shall appoint a facility operations manager or facility coordinator to oversee proper operation of the Center. A safety coordinator may be appointed to assist the manager. The extent of each authority shall be detailed in writing to ensure complete safety coverage of all facility operations. The Center Safety Office will interface with the facility managers or safety coordinators as appropriate to ensure proper safety program implementation.

8.6. FACILITY SAFETY MANAGEMENT PLAN

8.6.1. Safety Management Plan (SMP).

Centers shall document and maintain a written facility SMP for each major facility acquisition to monitor timely completion of all required life cycle safety program tasks. The SMP may be contractually proposed or prepared in-house. This plan shall be used to implement tailored safety requirements, including organizational responsibilities, resources, milestones, methods of accomplishment, depth of effort, and integration with other program engineering and management activities and related systems. For minor or normal acquisitions and facility modification projects, the SMP can be tailored but will include the appropriate local directives, instructions, and guidelines as a minimum.

8.6.1. Milestone Schedule.

The SMP shall contain a realistic milestone schedule commencing with the functional requirements and facilities concept development phase to monitor timely completion of all required safety program tasks for the facility project design. The milestone schedule shall also include safety management during construction, and the operation and maintenance considerations (instructions, training, provisioning of parts, special tools, and supplies) cited in Chapter 2 of NHB 7320.1B and NPG 8831.2, "Facilities Maintenance and Energy Management Handbook," for complex facility projects or the use of specialized equipment. All SMP milestones shall support the scheduled facility need date or occupancy date, as appropriate.

CHAPTER 9: FIRE SAFETY

9.1. PURPOSE

This chapter establishes the overall requirements for a NASA Fire Safety Program.

9.2. OBJECTIVES AND GOALS

The objective of NASA fire safety policy is to protect human life, property, and the environment from the risk of fire-related hazards. The goals are zero loss of life from fires, a reduction in number of fires to zero, protection for facilities and equipment to preclude major losses, and a reduction in the magnitude of loss for those fires that occur.

9.3. GENERAL

NASA will implement a comprehensive Fire Safety Program at each NASA Center. This program is accomplished through specific program requirements and procedures defined in NTS 1740.11, "Safety Standard for Fire Protection." The scope of the program includes:

9.3.1. Providing appropriate automatic fire detection and suppression systems for all facilities containing significant hazards, mission essential equipment, or permanently housed personnel in accordance with 29 CFR 1910 Subpart L.

9.3.2. Complying with NFPA and other nationally recognized building and fire safety codes and any applicable local codes in accordance with Public Law 100-678, "Public Buildings Amendments of 1988 (November 17, 1988; Section 6)."

9.3.3. Ensuring employees, other than trained professional firefighters, trained volunteers, or emergency response personnel, do not fight fires except in cases where the fire is incipient in nature.

9.3.4. Adhering to the more stringent of fire safety requirements imposed by local, State, or Federal agencies.

9.4. RESPONSIBILITIES

9.4.1. Each NASA organization is responsible for identifying and reducing fire risks, ensuring fire safety of its operations, and implementing the directives of this chapter. Centers are responsible for following applicable government laws and requirements for fire protection and life safety in construction and building codes as well as ensuring implementation of NASA operational fire safety directives.

9.4.2. The Authority Having Jurisdiction (AHJ) for NASA fire protection will be designated in writing by the Center Director and shall be a safety or fire protection professional.

9.4.3. Each Center's fire and safety organization shall review and approve all project plans and design documents with life safety and/or fire protection/prevention implications.

9.5. FIRE PROTECTION SURVEYS AND INSPECTIONS

Fire hazards will be identified through comprehensive fire risk evaluation, discrepancies documented, and abatement plans prepared for corrective action. Those items that cannot be corrected or funded locally must be forwarded to Headquarters for resolution. Engineering surveys and fire inspections will be conducted and documented.

9.6. FIRE PROTECTION SYSTEMS

9.6.1. Fire Protection Doctrine.

The nature of NASA's mission is such that a significant number of specialized facilities and operations exist along with the more conventional structures and work routines. As a result, difficulties arise in the determination of the required level of fire safety. In most instances, conventional fire protection doctrine and existing codes and standards are appropriate. However, specialized facilities may have fire risks not specifically addressed by conventional means. In those instances, safeguards can be assured by following the guidance outlined in this document and in NTS 1740.11.

9.6.2. Extinguishing Systems.

Extinguishing systems and fire extinguishers shall comply as a minimum with the National Fire Protection Association (NFPA) codes and standards. All fire protection equipment shall be Underwriter Laboratories (UL) listed or Factory Mutual (FM) approved.

9.7. FIREFIGHTING

Firefighting organizations may be established or provided to ensure adequate protection to life and property. NFPA recommendations and OSHA regulations shall be used for determining type, size, and training of firefighting organizations. When agencies external to NASA provide fire protection, the agreed-upon arrangement must be documented and retained on file.

9.8. EMERGENCY (PRE-FIRE) PLANNING AND PROCEDURES

Specialized facilities and critical areas that constitute a major portion of NASA operations demand a unique, preplanned response from the entire Agency. See NPD 8710.1, "Emergency Preparedness Program Policy;" NTS 1740.11; and respective emergency preparedness plans for further information on specific critical areas and emergency plan procedures.

9.9. FIRE SAFETY TRAINING

Training for NASA employees shall be in accordance with the requirements and guidelines contained in Chapter 4 of this document; 29 CFR 1910.38, "Employee Emergency Plans and Fire Prevention Plans;" and NTS 1740.11.

9.10. REPORTING

Reporting shall be an integral part of operational safety. Effective reporting procedures disseminate the knowledge and experience gained by one Center to the rest of NASA and the Federal Government. Reporting shall be in accordance with NPD 8621.1, "NASA Mishap Reporting and Investigating Policy."

9.11. REGULATIONS, CODES, AND STANDARDS

With the goal of protecting life and property, NASA organizations must comply with the requirements of the following documents in the design, construction, and operation of all NASA buildings and structures. (Conflicts shall be documented and sent to NASA Headquarters for review.)

9.11.1. Federal Documents

9.11.1.1. Public Law (PL) 100-678 (November 17, 1988; Section 6), "Compliance with Nationally Recognized Codes," which specifically recognizes NFPA Codes as a source document.

9.11.1.2. 29 Code of Federal Regulations (CFR) Part 1910 Subpart L, "Fire Protection."

9.11.2. NASA Documents

9.11.2.1. NTS 1740.11, This standard contains specific NASA requirements and guidelines for the implementation of a comprehensive fire protection program.

9.11.2.2. NPG 8715.x, "NASA Safety Manual Procedures and Guidelines."

- Paragraph 6.8, "Electrical Safety." Establishes codes that contain minimum fire safety requirements.

- Paragraph 6.16, "Launch Vehicle and Spacecraft Operations Safety." Provides summary guidance and requirements for protecting crew in a spacecraft workplace environment.

9.11.2.3. NPG 8060.1, "Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion." This Handbook contains methods to assess flammability of materials.

9.11.2.4. NPG 7320.1, "Facilities Engineering Handbook." This Handbook contains detailed NASA facility design and engineering requirements.

9.11.3 Other Standards.

The use of NFPA standards, including their appendices, is mandatory unless the requirements of the local codes are more stringent (see paragraph 9.2). Mandatory standards that need to be addressed are:

9.11.3.1. A nationally recognized building code or the appropriate local building codes.

9.11.3.2. NFPA fire standards, codes, and their appendices.

9.11.3.3. NFPA Life Safety Code Handbook.

9.1.3.3. NFPA National Electric Code Handbook.

APPENDIX A: ACRONYM AND ABREVIATION LIST

A-E	Architect-Engineering
AA	Associate Administrator
ACGIH	American Conference of Governmental Industrial Hygienists, Inc
ADTC	Armament Development Test Center
AFB	Air Force Base
AFFTC	Air Force Flight Test Center
AFOSH	Air Force Occupational Safety and Health
AHJ	Authority Having Jurisdiction
ALARA	As Low As Reasonably Achievable
ALSE	Aviation Life Support Equipment
AMO	Aircraft Management Office
ANSI	American National Standards Institute
ARAR	Accident Risk Assessment Report
ARC	Ames Research Center
ASAP	Aerospace Safety Advisory Panel
ASME	American Society of Mechanical Engineers
ASO	Aviation Safety Officer
ASRS	Aviation Safety Reporting System
ASTM	American Society for Testing and Materials
CAS	Contract Administration Services
CCB	Configuration Control Board
CDR	Critical Design Review
CFR	Code of Federal Regulations
	Crash, Fire, Rescue
CI	Configuration Item
CIL	Critical Items List
CMAA	Crane Manufacturers Association of America
CoDR	Concept Design Review
CoF	Construction of Facilities
COTR	Contracting Officers Technical Representative
CPR	Cardiac Pulmonary Resuscitation
CSFP	Critical Single Failure Point
CSC	Critical Software Command
DASHO	Designated Agency Safety and Health Official
DCMC	Defense Contracting Management Command
DCN	Document Control Number
DCR	Design Certification Review
DLA	Defense Logistics Agency
DLAM	Defense Logistics Agency Manual
DoD	Department of Defense

DOE	Department of Energy
DoL	Department of Labor
DOT	Department of Transportation
DR	Design Review
DRD	Data Requirement Description
EA	Environmental Assessment
EIS	Environmental Impact Statement
ELV	Expendable Launch Vehicle
EM	Engineering Memorandum
	Electronic Mail
	Exception Monitor
EO	Executive Order
EPA	Environmental Protection Agency
ESD	Electrostatic Discharge
ESMC	Eastern Space and Missile Center
ESMCR	Eastern Space and Missile Center Regulation
ETA	Event Tree Analysis
ETR	Eastern Test Range
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FDA	Food and Drug Administration
FHA	Fault Hazard Analysis
FI	Final Inspection
FM	Factory Mutual
FMEA	Failure Modes and Effects Analysis
FOD	Foreign Object Damage
FONSI	Finding of No Significant Impact
FPM	Facility Project Manager
FRR	Flight Readiness Review
FSAR	Final Safety Analysis Report
FTA	Fault Tree Analysis
FTR	Flight Test Requirement
GAO	General Accounting Office
GFE	Government Furnished Equipment
GFF	Government Furnished Facilities
GFP	Government Furnished Property
GHB	Goddard Handbook
GIDEP	Government-Industry Data Exchange Program
GSA	General Services Administration
GSE	Government Supplied Equipment
	Ground Servicing/Support Equipment
GSFC	Goddard Space Flight Center
HLTR	Hazard List Tracking Record
HOP	Hazardous Operating Procedure
HR	Hazard Report

IAOP	Intercenter Aircraft Operations Panel
ICAP	Interagency Committee for Aviation Policy
IHA	Integrated Hazard Analysis
	Interface Hazard Analysis
INSRP	Interagency Nuclear Safety Review Panel
IST	Initial System Test
ISTHA	Initial System Test Hazard Analysis
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KHB	Kennedy Handbook
KSC	Kennedy Space Center
LaRC	Langley Research Center
LFD	Light Emitting Diode
LeRC	Lewis Research Center
LLIS	Lessons Learned Information System
MSDS	Material Safety Data Sheet
MSE	Mission Safety Evaluation
MR	Mishap Report
MSPSP	Missile System Prelaunch Safety Package
NASA	National Aeronautics and Space Administration
NASC	National Aeronautics and Space Council
NDE	Nondestructive Evaluation
NEC	National Electric Code
NEPA	National Environmental Policy Act
NF	NASA Form
NFPA	National Fire Protection Association
NFS	NASA FAR Supplement
NHB	NASA Handbook
NHS	NASA Health Standard
NIOSH	National Institute of Occupational Safety and Health
NMI	NASA Management Instruction
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NRC	Nuclear Regulatory Communication
NSIS	NASA Safety Information System
NSRS	NASA Safety Reporting System
NSS	NASA Safety Standard
O&E	Operations and Engineering
O&SHA	Operating and Support Hazard Analysis
OHA	Operating Hazard Analysis
OHO	Occupational Health Office
OIC	Official-in-Charge
OMB	Office of Management and Budget
OP	Occupancy Permit
	Operating Procedure

ORI	Operational Readiness Inspection
ORR	Operational Readiness Renew
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OSMA	Office of Safety and Mission Assurance
OSTP	Office of Science and Technology Policy
PAO	Public Affairs Officer
PAR	Prelaunch Assessment Review
PAR-P	Problem Assessment Review - Payloads
PDR	Preliminary Design Review
PER	Preliminary Engineering Report
PFI	Pre-Final Inspection
PHA	Preliminary Hazard Analysis
PIC	Pilot-in-Command
PL	Public Law
PM	Program Manager
PS	Pressurized System
PSAR	Preliminary Safety Analysis Report
psig	Per square inch gage
PSSP	Project System Safety Panel
PV	Pressurized Vessel
R&D	Research and Development
RAC	Risk Assessment Code
RFP	Request for Proposal
RSO	Range Safety Office
SAR	Safety Assessment Report
	Safety Analysis Report
SAS	Safety Analysis Summary
SCA	Sneak Circuit Analysis
SCAPE	Self-Contained Atmospheric Protective Ensemble
SCBA	Self-Contained Breathing Apparatus
SCR	System Concept Review
SCUBA	Self-Contained Underwater Breathing Apparatus
SEB	Source Evaluation Board
SER	Safety Evaluation Report
SHA	System Hazard Analysis
SIP	Standardization Instructor Pilot
SMA	Safety and Mission Assurance
SMP	Safety Management Plan
SOW	Statement of Work
SPP	Safety Program Plan
SR&QA	Safety, Reliability and Quality Assurance
SRM&QA	Safety, Reliability, Maintainability, and Quality Assurance
SSB	Source Selection Board
SSC	Stennis Space Center

SSHA	Subsystem Hazard Analysis
SSM	System Safety Manager
SSP	Space Shuttle Program
SSPP	System Safety Program Plan
SSRP	System Safety Review Panel
SSSC	Senior Safety Steering Committee
	System Safety Steering Committee
STS	Space Transportation System
SWHA	Software Hazard Analysis
TLV	Threshold Limit Value
TMIG	Telemetry Inertial Guidance
TP	Test Procedure
TRR	Test Readiness Review
UL	Underwater Laboratories
USAR	Updated Safety Analysis Report
USFA	United States Fire Administration
V	Volt
WFF	Wallops Flight Facility
WSMCR	Western Space and Missile Center Regulation
WSMR	White Sands Missile Range
WTR	Western Test Range
WX	Weather

APPENDIX B: GLOSSARY OF SAFETY AND RISK MANAGEMENT TERMS

ACCEPTANCE TESTING — Tests to determine that a part, component, subsystem, or system is capable of meeting performance requirements over the environmental and operating ranges prescribed in the specification documents.

ACCEPTED RISK— A hazard whose risk is not completely mitigated and that has been accepted by top program and safety management.

ACCIDENT PREVENTION — Methods and procedures used to eliminate the causes that could lead to a mishap.

ACTION CENTERS — Emergency centers set up by the appropriate Center official or program official to coordinate all communications, responses, and other actions for mishaps that have international, national, or regional implications; high visibility; or major public interest.

APPLIED LOAD (STRESS) — Actual load (stress) imposed on a system.

ARMING — Bringing a device or system to a state or condition that will allow its subsequent activation.

ASSESSMENT— Review or audit process, using predetermined methods, that evaluates hardware, software, procedures, technical and programmatic documents, and the adequacy of their implementation.

AUDIT— Formal review to assess compliance with hardware or software requirements, specifications, baselines, safety standards, procedures, instructions, codes, and contractual and licensing requirements.

AUTHORITY HAVING JURISDICTION (AHJ) — The AHJ is the organization, office, or individual responsible for "approving" equipment, an installation, or a procedure. The AHJ for NASA fire protection will be designated in writing by the Center Safety Director and shall be a safety or fire protection professional.

AVAILABILITY — Measure of the percentage of time that an item operates as intended.

BIOMECHANICS — Interdisciplinary science (comprising mainly anthropometry, mechanics, physiology, and engineering) of the mechanical structure and behavior of biological materials. It concerns primarily the dimensions and mass properties of body segments.

CATASTROPHIC — A hazard that could result in a mishap causing fatal injury to personnel, and/or loss of one or more major elements of the flight vehicle or ground facility.

CATASTROPHIC CONDITION — Hazardous condition that may cause death or major system destruction on the ground, or loss of crew or vehicle during the mission.

CATASTROPHIC FAILURE — Failure that causes loss of life or loss of a system or element thereof.

CERTIFICATION TEST — Test whose objective is to determine and then certify that system specifications are satisfied or personnel skills are present.

CERTIFIED PERSONNEL — Personnel who have completed required training and whose specified knowledge or proficiency in a skill has been demonstrated and documented.

CLOSE CALL — An occurrence in which there is no injury, no significant equipment/property damage (less than $1000), and no significant interruption of productive work but which possesses a high severity potential for any of the mishaps as defined as Type A, B, C Mishap, Mission Failure, and Incident.

COLLATERAL INVESTIGATION — A line management investigation, formal or informal, whose objectives lie outside the scope of NPD 8621.1, e.g., to assign blame or guilt and recommend punitive actions.

CONFIGURATION ITEM — An item that is designated for configuration management.

CONTRACTOR SAFETY PLANS — Written plans prepared by the contractor detailing the overall safety program that will cover the employees, equipment, and facilities used to fulfill the contract.

CONTRIBUTING CAUSE — A factor, event, or circumstance which led, directly or indirectly, to the primary cause, or which contributed to the severity of the mishap.

CONTROLLED (RISK) HAZARD — The likelihood of occurrence or severity of the associated undesirable event has been reduced to an acceptable level through the imposition of appropriate, readily implementable, verifiable controls, resulting in minimal residual risk.

CORRECTIVE ACTION — Action taken to preclude continuation of a discrepancy, problem or recurrence of a mishap.

COSTS (MISHAP) — Direct costs of repair, retest, program delays, replacement, or recovery of NASA materials including hours, material, and contract costs, but excluding indirect costs of cleanup, investigation (either by NASA, contractor, or consultant), injury, or normal operational shutdown. Materials or equipment replaced by another organization at no cost to NASA will be calculated at "book" value. This includes those mishaps covered by insurance.

CREDIBLE CONDITION (EVENT) — Condition (event) that reasonably may be anticipated and planned for based on experience with or analysis of a system.

CREW RATING — Certifying the incorporation of enhanced environmental support, reliability, and safety features into the design and operation of hardware and software essential for the preservation of life during crewed tests or operations.

CRITICAL LIFTING OPERATIONS — Lifting and lowering operations involving major programmatic or institutional hardware that is irreplaceable, or will cause serious program or mission delays if damaged, or is hazardous to personnel if dropped or uncontrolled, or will require special budgetary actions to repair damages suffered from lifting malfunctions.

CRITICAL SINGLE FAILURE POINT (CSFP) — A single item or element, essential to the safe functioning of a system or subsystem, whose failure in a life or mission essential application would cause serious program or mission delays or be hazardous to personnel.

CRITICAL SOFTWARE COMMAND (CSC) — A command that either removes a safety inhibit or creates a hazardous condition.

DESIGN BURST PRESSURE — Pressure at which an element of a pressurized system would be expected to burst if it meets the exact design conditions.

DESIGN MARGIN — Percent by which a factor of safety of 1.0 is exceeded or deficient.

DEVIATION — A variance that authorizes departure from a particular safety requirement where the intent of the requirement is being met through alternate means that provide an equal or greater level of safety.

ELIMINATED HAZARD — A hazard that has been eliminated by completely removing the hazard causal factors.

EMERGENCY — Unintended circumstance bearing clear and present danger to personnel or property, which requires an immediate response.

EVENT TREE ANALYSIS (ETA) — An analysis that traces the effect of a mishap and leads to all possible consequences through visualization of the positive and negative sides for each event using a type of logic tree. Event trees are complements to fault trees. This is an inductive logic method for identifying the various possible outcomes of a given initiating event.

EXPOSURE — (1) Vulnerability of a population, property, or other value system to a given activity or hazard; or (2) other measure of the opportunity for failure or mishap events to occur.

FACTOR OF SAFETY (SAFETY FACTOR) — Ratio of the design condition to the maximum operating conditions specified during design (See also Safety Margin and Margin of Safety.)

FAIL-OPERATIONAL — Ability to sustain a failure and retain full operational capability.

FAIL-SAFE — Ability to sustain a failure and retain the capability to safely terminate or control the operation.

FAILURE — Inability of a system, subsystem, component, or part to perform its required function within specified limits.

FAILURE ANALYSIS — A systematic examination of a failed item or system to identify the failure mode and cause.

FAILURE CAUSE — Physical or chemical process, design defect, quality defect, or other process that initiates a sequence of events leading to failure.

FAILURE EFFECT — Consequence of a failure mode on the operation, function, or status of an item or system.

FAILURE MODE — Particular way in which a failure can occur, independent of the reason for failure.

FAILURE MODES AND EFFECTS ANALYSIS (FMEA) — A bottoms up systematic, inductive, methodical analysis performed to identify and document all identifiable failure modes at a prescribed level and to specify the resultant effect of the modes of failure. It is usually performed to identify critical single failure points (CSFPs) in hardware. In relation to formal hazard analyses, FMEA is a subsidiary analysis.

FAILURE RATE — Number of failures per unit of time or other measure of opportunity for failures to occur.

FAULT DETECTION — Process that discovers or is designed to discover faults.

FAULT HAZARD ANALYSIS (FHA) — Analysis performed during design resulting in the identification, evaluation, and control of hazards resulting from piece-part or component faults.

FAILURE TOLERANCE — Built-in capability of a system to perform as intended in the presence of specified hardware or software failures.

FAULT TREE — A schematic representation resembling an inverted tree that depicts possible sequential events (failures) that may proceed from discrete credible failures to a single undesired final event (failure). A fault tree is created retrogressively from the final event by deductive logic.

FAULT TREE ANALYSIS (FTA) — An analysis that begins with the definition or identification of an undesired event (failure). The fault tree is a symbolic logic diagram showing the cause-effect relationship between a top undesired event (failure) and one or more contributing causes. It is a type of logic tree that is developed by deductive logic from a top undesired event to all subevents that must occur to cause it.

FINDING — A conclusion based on facts established during the investigation by the investigating authority.

FIRMWARE — Computer programs and data loaded in a class of memory that cannot be dynamically modified by the computer during processing.

FIRST AID — Emergency care or treatment given to an ill or injured person before regular medical aid can be obtained at a medical care facility (hospital). The following procedures are generally considered first aid treatment (e.g., one-time treatment and subsequent observation of minor injuries). These injuries are not considered to be NASA Reportable Mishaps if the work-related injury does not involve loss of consciousness, restriction of work or motion, or transfer to another job:

- Application of antiseptics during first visit to medical personnel.
- Treatment of first degree burn(s).
- Application of bandage(s) during any visit to medical personnel.
- Use of elastic bandage(s) during first visit to medical personnel.
- Removal of foreign bodies not embedded in eye if only irrigation is required.
- Removal of foreign bodies from wound if procedure is not complicated and is, for example, by tweezers or other simple technique.
- Use of nonprescription medications and administration of single dose of prescription medication on first visit for minor injury or discomfort.
- Soaking therapy on initial visit to medical personnel or removal of bandages by soaking.
- Application of hot or cold compress(es) during first visit to medical personnel.
- Application of ointments to abrasions to prevent drying or cracking.
- Use of heat therapy during first visit to medical personnel.
Negative x-ray diagnosis.
- Observation of injury during visit to medical personnel.

FLIGHT HARDWARE — Hardware designed and fabricated for ultimate use in a vehicle intended to fly.

FRACTURE MECHANICS — Engineering methods used to predict flaw-growth and fracture behavior of materials and structures containing cracks or crack-like flaws.

GROUND SUPPORT EQUIPMENT — Ground-based equipment used to store, transport, handle, test, check out, service, and control aircraft, launch vehicles, spacecraft, or payloads.

HANDLERS OF HAZARDOUS MATERIAL — Individuals who handle but who do not open or otherwise disturb the integrity of the basic, properly packaged, shipping container that holds the hazardous material. As an example, this includes personnel who prepare, package, mark, or transport hazardous material. Personnel who reduce palletized or otherwise combined items into smaller increments, without exposing the hazardous material, are considered handlers.

HAZARD — Existing or potential condition that can result in or contribute to a mishap.

HAZARD ANALYSIS — Identification and evaluation of existing and potential hazards and the recommended mitigation for the hazard sources found.

HAZARD ANALYSIS REPORT — System safety document that summarizes results of the hazard analyses performed on a system or activity.

HAZARD CONTROL — Means of reducing the risk of exposure to a hazard.

HAZARD LIST — Listing of all identifiable and known hazards.

HAZARD PRIORITIZATION — Used in risk management, ranking of hazards in order of risk severity by program and safety management for formal action to reduce the level of risk.

HAZARD PROBABILITY — Likelihood of occurrence, stated in qualitative or quantitative terms, of the aggregate of conditions that result in a specific hazard.

HAZARD REPORT (HR) CLOSURE CLASSIFICATION — Report closures are classified as eliminated hazard, controlled hazard, or accepted risk hazard. An HR when closed will have one of the following classifications: ELIMINATED HAZARD, CONTROLLED HAZARD, or ACCEPTED RISK

HAZARD REPORT (HR) STATUS — Report status is cited as follows:

1. CLOSED — Corrective action to eliminate or control the hazard has been implemented or scheduled for implementation before the effectively identified in the HR; or

2 OPEN — An HR status is open when corrective action to eliminate or control the hazard has not been completed and the corrective action is not scheduled to be performed.

HAZARDOUS EVENT — Event that contributes to a hazard.

HAZARDOUS MATERIAL — Defined by law as "a substance or materials in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce" (49 U.S.C 1802). The Secretary of Transportation has developed a list of materials that are hazardous which may be found in 49 CFR 172.101. Typical hazardous materials are those that may be highly reactive, poisonous, explosive, flammable, combustible, corrosive, radioactive, produce contamination or pollution of the environment, or cause adverse health effects or unsafe conditions.

HAZARDOUS OPERATION — Any operation involving material or equipment that has a high potential to result in loss of life, serious injury to personnel or damage to systems, equipment, or facilities.

HAZARDOUS OPERATION SAFETY CERTIFICATION — Certification required for personnel who perform those tasks that potentially have an immediate danger to the individual (death/injury), if not done correctly, could create a danger to other individuals in the immediate area (death or injury), and present a danger to the environment.

HIGH VALUE — Facilities/equipment valued at 1 million ($1,000,000) dollars and above.

HUMAN ENGINEERING — Area of engineering that applies scientific knowledge to the design of systems and operations to achieve effective human-system integration.

HUMAN FACTORS ENGINEERING — Area of engineering dealing with human biomedical and psychosocial characteristics. It includes, but is not limited to, principles and applications in the areas of human engineering, personnel selection, training, life-support, job performance aids, and human performance evaluation.

IMMEDIATELY REPORTABLE MISHAPS — All Type A and B mishaps and mission failures that require immediate telephonic notification to local and Headquarters safety officials.

INCIDENT — A mishap consisting of less than Type C mishap severity of injury to personnel (more than first-aid severity) and for property damage equal to or greater than $1,000 but less than $25,000.

INDEPENDELIT VERIFICATION AND VALIDATION — Test and evaluation process by a third party.

INDEPENDENT INHIBIT — An inhibit that will continue to operate independent of other design features.

INHIBIT — Design feature that prevents operation of a function.

INTEGRATED HAZARD ANALYSIS — Comprehensive evaluation of hazards, taking into account all subsystems and elements that are included in the overall system being analyzed, including the system, and operational and environmental envelopes.

INTERFACE HAZARD ANALYSIS (IHA) — Evaluation of hazards which cross the interfaces between a specified set of components, elements, or subsystems.

INTERLOCK — Hardware or software function that prevents succeeding operations when specific conditions are satisfied.

LIMIT LOAD — Maximum combination of loads which a structure is expected to experience in a specified operational environment.

MARGIN OF SAFETY — Deviation of the actual (operating) factor of safety from the specified factor of safety. Can be expressed as a magnitude or percentage relative to the specified factor of safety.

MEDICAL TREATMENT — The following procedures are generally considered medical treatment. Any work-related injury/illness for which this type of treatment was provided or should have been provided is considered a NASA Reportable Mishap:

- Treatment of infection.
- Application of antiseptics during second or subsequent visit to medical personnel.
- Treatment of second or third degree burn(s).
- Application of sutures (stitches).
- Application of butterfly adhesive dressing(s) or steri strip(s) in lieu of sutures.
- Removal of foreign bodies embedded in the eye.
- Removal of foreign bodies from wound if procedure is complicated because of depth of embedment, size, or location.
- Use of prescription medications (except a since dose administered on first visit for minor injury or discomfort).
- Use of hot or cold soaking therapy during second or subsequent visit to medical personnel.
- Application of hot or cold compress(es) during second or subsequent visit to medical personnel.
- Cutting away dead skin (surgical debridement).
- Application of heat therapy during second or subsequent visit to medical personnel.
- Use of whirlpool bath therapy during second or subsequent visit to medical personnel.
- Positive x-ray diagnosis (fractures, broken bones, etc).
- Admission to a hospital or equivalent medical facility for treatment (not merely observation).

MINOR RADIOACTIVE SOURCES — Quantities of minor radioactive sources are defined in terms of the level of review and reporting procedures required. Small quantities of radioisotopes as set forth by the four Radiotoxicity Groups and Hazard Categories which are further defined in the June 16, 1970 National Aeronautics and Space Council document, "Nuclear Safety Review and Approval Procedures for Minor Radioactive Sources in Space Operations," for a variety of application, i.e., standards for instrumentation calibration, dial illumination, heat sources for vital equipment, etc.

MISSION CRITICAL — Item or function that must retain its operational capability for mission conduct.

MISSION FAILURE — Any mishap (event) of such a serious nature that it prevents accomplishment of a majority of the primary mission objectives. A mishap of whatever intrinsic severity that, in the judgment of the Program Associate Administrator, in coordination with the Associate Administrator for Safety and Mission Assurance, prevents the achievement of primary mission objectives as described in the Mission Operations Report or equivalent document.

MISSION SAFETY EVALUATION (MSE) REPORT — A formal report for a specified mission to document the independent safety evaluation of safety risk factors that represent a change, or potential change, to the risk baseline of the Program

NASA CONTRACTOR MISHAP — Any Type A, Type B, or Type C Mishap, Mission Failure, or Incident that involves only NASA contractor personnel, equipment, or facilities in support of NASA operations.

NASA MISHAP — Any unplanned occurrence, event, or anomaly that meets one of the criteria of Type A, B, or C Mishap, Mission Failure, and Incident. Injury to a member of the public while on NASA facilities is also defined as a NASA mishap.

NASA REPORTABLE MISHAP — Any work-related mishap resulting in a death, permanent disability, or hospitalization of five or more persons; or occupational injury or illness which results in a lost workday case or medical treatment beyond first aid, loss of consciousness, restriction of work or motion, or transfer to another job; or damage to, or loss of, equipment or property damage equal to, or greater than, $1,000. Mission failures and close calls with potential as a Type A or B mishap are also reportable.

NASA SAFETY STANDARD (NSS) — A NASA safety document that requires conditions, or the adoption or use of one or more practices, means, methods, operations, or processes, reasonably necessary or appropriate to provide for safe employment and places of operation. The document is promulgated by the NASA Office of Safety and Mission Assurance, and implemented and enforced by the Center Safety and Mission Assurance organization.

NONCRITICAL LIFTING — A lifting operation whose failure or malfunction (loss of control, dropping a load, etc.) would not cause loss of life, loss of space vehicle, loss of payload, loss of mission essential hardware, or damage to flight or space hardware.

NONDESTRUCTIVE EVALUATION (NDE) — Test and inspection methods used to determine the integrity of equipment that do not involve destruction of the test object. Examples are ultrasonic, magnetic particle, eddy current, x-ray, dye penetrant, etc.

OBSERVATION — A factor, event, or circumstance deserving comment but not found to be a contributing or potential cause of the mishap being investigated.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) AS RECORDABLE MISHAP — An occupational death, injury, or illness that must be recorded subject to OSHA requirements in 29 CFR Part 1960 and Part 1910.

OPERATING AND SUPPORT HAZARD ANALYSIS (O&SHA) — An analysis performed to identify hazards and recommend risk reduction alternatives in procedurally controlled activities during all phases of intended use.

OPERATING HAZARD ANALYSIS (OHA) — An analysis that examines the operator interface during system operation and maintenance actions. Because the operator actions are not defined until late in the system development program, corrective action resulting from this analysis will seldom be a design change. This analysis also determines certification and training requirements and safety inputs to technical manuals, warning signs, and safety placards.

OPERATIONAL SAFETY — That portion of the total NASA safety program dealing with safety of personnel and equipment during launch vehicle ground processing, normal industrial and laboratory operations, special high hazard tests and operations, aviation operations, use and handling of hazardous materials and chemicals from a safety viewpoint, and design, construction, and use of facilities.

POTENTIAL CAUSE — A factor, event, or circumstance which could have been a contributing cause of a similar mishap, but in the investigated case, causal relationship was not proven.

PRELIMINARY HAZARD ANALYSIS (PHA) — A gross study of the initial system concepts. It is used to identify all of the energy sources that constitute inherent hazards. The energy sources are examined for possible accidents in every mode of system operation. The analysis is also used to identify methods of protection against all of the accident possibilities.

PRESSURE VESSEL — Any vessel used for the storage or handling of a fluid under positive pressure. A pressure system is an assembly of components under pressure, e.g., vessels, piping, valves, relief devices, pumps, expansion joints, gages.

PRIMARY EVENT (FAULT TREE) — A fault, failure, or event that initiates, or participates in a mishap sequence.

PRIMARY CAUSE — The major anomalous event immediately preceding a mishap in the absence of which the mishap would not have occurred.

PROOF LOAD TEST — A load test performed prior to first use, after major modification of the load path, or at other prescribed times. This test verifies material strength, construction, and workmanship and uses a load greater than the rated load

RANGE SAFETY — Application of safety policies, principles, and techniques to ensure the control and containment of flight vehicles to preclude an impact of the vehicle or its pieces outside of predetermined boundaries from an abort which could endanger life, or cause property damage or embarrassment to the Government. Where the range has jurisdiction, pre-launch preparation is included as a safety responsibility.

RATED LOAD TEST — A load test performed at predetermined intervals with a load equal to the rated load.

REDUNDANCY — Use of more than one independent means to accomplish a given function.

RESIDUAL RISK — Risk that remains from a hazard after all mitigation and controls have been applied.

RISK — As applies to safety, exposure to the chance of injury or loss. It is a function of the possible frequency of occurrence of an undesired event, of the potential severity of resulting consequences, and of the uncertainties associated with the frequency and severity.

RISK CONTRIBUTORS LIST — List of hazards and their associated severity and probability contributing to a risk.

RISK MANAGEMENT — Process of balancing risk with cost, schedule, and other programmatic considerations. It consists of risk identification, risk assessment, decision making on the disposition of risk, and tracking the effectiveness of the results of the action resulting from the decision.

RISK (SAFETY) ASSESSMENT — Process of qualitative risk categorization or quantitative risk (safely) estimation, followed by the evaluation of risk significance.

SAFETY ANALYSIS — Generic term for a family of analyses, which includes but is not limited to: preliminary hazard analysis, system (subsystem) hazard analysis, operating hazard analysis, software hazard analysis, sneak circuit, and others.

SAFETY ANALYSIS REPORT (SAR) — A safety report of considerable detail prepared by the contractor detailing the safety features of a particular nuclear system or source. The SAR is submitted to the Interagency Nuclear Safety Review Panel (INSRP) for review.

SAFETY ANALYSIS SUMMARY (SAS) — A brief summary of safety considerations for minor sources; a safety report of less detail than the SAR, prepared and reviewed in the same manner as the SAR.

SAFETY ASSISTANCE VISIT — Informal on-site evaluations by specialists and safety personnel who, after making spot checks and sampling visits and holding discussions with appropriate levels of management, provide informal or formal reports to the affected organization.

SAFETY ASSURANCE — The attainment of acceptable risk for the safety of personnel, equipment, facilities, and the public during and from the performance of operations.

SAFETY CRITICAL — Term describing any condition, event, operation, process, equipment, or system that could lead to severe injury or major damage if performed or built improperly.

SAFETY CRITICAL FUNCTION — A system, equipment, or facility function that, by not performing as intended, causes a safety-critical condition.

SAFETY CRITICAL (CONDITION) HAZARD — A hazardous condition that may lead to loss of life, severe injury, or major property damage.

SAFETY CRITICAL ITEM — Single failure point or other element or item in a life or mission-essential application that, as determined by the results of failure modes and effects analysis or other safety analysis, is essential to the safe functioning of a system or subsystem.

SAFETY DEVICE — A device that is part of a system, subsystem, or equipment that will reduce or make controllable hazards which cannot be otherwise eliminated through design selection.

SAFETY EVALUATION REPORT (SER) — A safety report prepared by the INSRP detailing the safety of a particular source or system based on their own assessment of the contractor-supplied SAR, SAS, and other data

SAFETY MANAGEMENT PLAN (SMP) — A document developed for a program or project to be the vehicle for safety task planing. Included in the SMP will be detailed task requirements for the system safety task tailored for the specific program or project, the program organization, safety relationships and responsibilities, task reporting channels, the required hazard analysis methodologies, and the program/project milestones.

SAFETY MARGIN — Difference between as-built factor of safety and the ratio of actual operating conditions to the maximum operating conditions specified during design.

SAFETY OVERSIGHT — Maintaining functional awareness of program activities on a real-time basis to ensure risk acceptability.

SAFETY PROFESSIONAL — A representative of the Safety Office.

SAFETY PROGRAM — The implementation of a formal comprehensive set of safety procedures, tasks, and activities to meet safety requirements, goals, and objectives.

SAFETY PROGRAM PLAN (SPP) — A document that describes the safety assurance tasks to be implemented throughout a program/project or contract, including methods of approach, safety milestones, and assigned responsibilities for fulfilling these tasks. The SPP will explain in detail how the requirements of the Safety Management Plan and the NASA FAR Supplement will be implemented.

SAFING — Sequence of events necessary to reconfigure a system to a lower level of risk

SENIOR SAFETY STEERING COMMITTEE (SSSC) — The SSSC comprises senior Center safety management personnel and personnel from the NASA Safety and Risk Management Division, Space Station Program, and Headquarters Personnel Branch. The SSSC will provide a forum to address and investigate system and industrial safety issues that cannot be resolved at the local safety levels and to facilitate appropriate resolutions NASA-wide.

SEVERITY LEVEL — An assessment of the most severe effects(s) of a hazard. Severity level will be categorized as CATASTROPHIC, CRITICAL, or MARGINAL.

SINGLE FAILURE POINT — An independent element of a system (hardware, software, or human) the failure of which would result in loss of objectives, hardware, or crew.

SNEAK CIRCUIT — Unintended system design condition in electrical circuits or software source code not caused by a failure, which can inhibit wanted functions or cause unintended functions to occur through a stimulus, path, or a response relationship.

SNEAK CIRCUIT ANALYSIS (SCA) — A technique by which the system safety engineer can identify latent conditions (e.g., electrical, hydraulic, or other control systems) not caused by component failure that can inhibit desired functions or cause undesired functions to occur.

SOFTWARE HAZARD ANALYSIS — Identification and verification of adequate software controls and inhibits; and the identification, analysis, and elimination of discrepancies relating to safety critical command and control functions.

SOFTWARE SAFETY CRITICAL — Software operations that, if not performed, performed out of sequence, or performed incorrectly, could directly or indirectly cause or allow a hazardous condition to exist.

SYSTEM CONCEPT REVIEW (SCR) — A review conducted when sufficient system functional requirements have been established. Safety verifies the adequacy of the system requirements definitions, ensures designers are acquainted with interface technical requirements, reviews design approaches to be optimized and complete, and evaluates system interfaces for risks.

SYSTEM SAFETY — Application of engineering and management principles, criteria, and techniques to optimize safety and reduce risks within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle.

SYSTEM SAFETY MANAGER (SSM) — A designated management person who, qualified by training and/or experience, is responsible to ensure accomplishment of system safety tasks.

SYSTEM SAFETY REVIEW PANEL (SSRP) — An independent panel chartered by the Program Manager to enhance the safety of the program through the ongoing conduct of independent peer safety reviews at appropriate Program milestones, and ad hoc reviews as necessary. The size and composition of the panel shall be determined by the size, type, and safety risk potential of the Program and shall be chaired by a safety professional not assigned to the Program.

TYPE A MISHAP — A mishap causing death and/or damage to equipment or property equal to or greater than $1,000,000. Mishaps resulting in damage to aircraft or space hardware, i.e., flight and ground support hardware, meeting this criterion are included. A Type A mishap also includes a test failure if the damage was unexpected or unanticipated or if the damage is likely to have significant program impact or visibility.

TYPE B MISHAP — A mishap resulting in permanent disability to one or more persons, hospitalization (for other than observation) of five or more persons, and/or damage to equipment or property equal to or greater than $250,000 but less than $1,000,000. Mishaps resulting in damage to aircraft or space hardware that meet these criteria are included, as are test failures where the damage was unexpected or unanticipated.

TYPE C MISHAP — A mishap resulting in damage to equipment or property equal to or greater than $25,000 but less than $250,000, and/or causing occupational injury or illness that results in a lost workday case. Mishaps resulting in damage to aircraft or space hardware that meet these criteria are included, as are test failures where the damage was unexpected or unanticipated.

USERS OF HAZARDOUS MATERIAL — Users are those personnel who open the incremental hazardous material shipping container, thereby exposing the material to mix, transfer, burn, freeze, pour, vent, react, dispose, or otherwise use or alter the material.

VACUUM SYSTEM — An assembly of components under vacuum, including vessels, piping, valves, relief devices, pumps, expansion joints, gages, etc

VACUUM VESSEL — A vessel in which the internal pressure has been reduced to a level less than that of the surrounding atmosphere.

VALIDATION — (1) An evaluation technique to support or corroborate safety requirements to ensure necessary functions are complete and traceable; or (2) the process of evaluating software at the end of the software development process to ensure compliance with software requirements.

VARIANCE — Documented and approved permission to perform some act contrary to established requirements.

VERIFICATION (Software) — (1) The process of determining whether the products of a given phase of the software development cycle fulfill the requirements established during the previous phase (see also validation); or (2) formal proof of program correctness; or (3) the act of reviewing, inspecting, testing, checking, auditing, or otherwise establishing and documenting whether items, processes, services, or documents conform to specified requirements.

WAIVER — A variance that authorizes departure from a particular safety requirement where an increased level of risk has been accepted.

APPENDIX C: SAFETY MOTIVATION AND AWARDS PROGRAM

1. The following awards represent NASA's primary means for recognizing outstanding safety performance:

a. NASA Honor Awards. These awards are approved by the Administrator and represent the highest honorary recognition bestowed by NASA. Federal and non-federal personnel making significant safety contributions may be nominated for these awards following the guidelines provided in NPD 3451.1, “The NASA Awards and Recognition Program."

b. NASA Safety and Risk Management Division Awards. This awards program is administered by the NASA Safety Division It is specifically designed to recognize and encourage significant achievements and initiatives by NASA personnel in program and operational safety.

c. NASA Space Flight Safety Award. This award is managed by the Space Flight Safety Panel in accordance with NPC 1157.66, "NASA Space Flight Safety Panel." It is bestowed in recognition of contributions to flight safety made through design, device, or practice. The purpose of the award is to acknowledge the individuals whose personal efforts, above and beyond their job commitment, result in significant, direct contributions to flight safety. The award is given to both individuals and groups. Every Government and industry employee supporting NASA's manned space effort is eligible for this award.

d. Center Safety Awards. The majority of NASA safety awards are issued at the local level as part of each Center's overall safety effort. Safety programs at NASA Centers shall include an awards program, designed in accordance with this document, to recognize and encourage safety in all operations.

2. NASA safety awards shall be properly designed to motivate and maintain safe behavior. The following principles shall be considered when developing safety awards:

a. Individual awards are generally more effective than group awards. The monetary value of the award is relatively unimportant. Expensive awards may actually foster competition and ill feelings that defeat the purpose of the program. The most appropriate award is one that individuals can keep and display.

b. The manner in which the award is presented is as important as the award itself. The award should be presented publicly to effectively satisfy the individual's/group's need for recognition and thereby provide an incentive for other personnel.

c. Any award based on competition must be carefully designed to avoid possible negative aspects. (For example: Employees involved in a competition to reduce on-the job injuries have been known to avoid seeking medical attention for an injury so that it would not be reported.)

d. The safety awards program should be part of the participating safety program and include all personnel.

e. Award presentations and the safety contributions made by award recipients shall be sufficiently publicized to heighten employee safety awareness and to encourage active employee participation in all efforts designed to improve safety performance.

f. Awards shall be granted on the basis of merit without regard to age, color, handicap, marital status, national origin, politics, participation or nonparticipation in a labor organization, race, religion, or sex.

g. NASA awards for safety excellence shall be granted based on specific published criteria. Nominations shall be evaluated against the individual awards criteria and not against any unwritten standards or interpretations.

3. In conjunction with safety awards, NASA safety programs may distribute items of minimal value to individuals as a means of promoting safe work practices and heightening safety awareness. The following apply to the purchase and distribution of safety promotional items:

a. Procurements made with Federally appropriated funds are subject to the rulings of the General Accounting Office (GAO). Safety promotional items usually are interpreted by GAO as personal gifts, and therefore have not been allowed. It is recommended that non-appropriated funds be used for the procurement of safety promotional items whenever possible.

b. Safety promotional items shall be distributed for valid reason and shall not be given with such frequency that they lose meaning.

c. The responsible NASA safety organization shall clearly define the purpose of each award, those who are eligible, and the criteria for selection.

d. All items shall be clearly identified as NASA safety program items via printed markings and/or safety logos.

APPENDIX D: ANALYSIS TECHNIQUES

The purpose of safety analysis is to provide a means to systematically and objectively identify hazards, determine their risk level and provide the mechanism for their elimination or control. Safety analysis is an iterative process that begins in the Concept Phase and extends throughout the life cycle including the Disposal Phase.

1. Functions supported by the analysis include:

a Providing the foundation for the development of safety criteria and requirements.

b. Determining whether and how the safety criteria and requirements provided to engineering have been included in the design.

c. Determining whether the safety criteria and requirements created for design and operations have provided an acceptable level of risk for the system.

d. Providing part of the means for imposing pre-established safety goals.

e. Providing a means for demonstrating that safety goals have been met.

The extent and depth of analysis required to meet these five functions will be determined by system complexity and loss potential.

2. During the hazard identification process, it is essential to remain nonjudgmental about the associated probability, severity, and corrective actions. Once identified, hazards shall then be ranked by severity, probability of occurrence, and program impact (risk assessment). Sufficient analysis must be performed to assess the likelihood of occurrence (usually qualitative for early assessments) for each identified undesired event.

3. There are several types of analyses necessary to identify all the hazards; some are specialized and others, as designs mature, build on previously accomplished analyses.

4. Analyses such as the ones described below shall be employed to the extent and depth determined by the SSM as necessary to fully assess the risk to personnel, equipment, and property:

a. <u>Preliminary Hazard Analysis (PHA)</u>. In many ways the PHA is the most important of the safety analyses because it is the foundation on which the rest of the safety analyses and the system safety tasks are built. It documents which generic hazards are associated with the design and operational concept. This provides the initial framework for a master listing (or hazard catalog) of hazards and associated risks that require tracking and resolution during the course of the program design and development. The PHA also may be used to identify safety-critical systems that will require the application of Failure Modes and Effects Analysis and further hazard analysis during the design phases.

b. The program shall require and document a PHA to obtain an initial listing of risk factors for a system concept. The PHA effort shall be started during the concept exploration phase or earliest life cycle phases of the program. A PHA considers hardware, software, and the operational concepts. Hazards identified in the PHA will be assessed for risk based on the best available data, including mishap data from similar systems, other lessons learned, and hazards associated with the proposed design or function. Mishap and lessons learned information are available in the Incident Reporting Information System (IRIS) and the Lessons Learned Information System (LLIS). The risk assessment developed from the PHA will be used to ensure safety considerations are included in tradeoff studies of design alternatives; development of safety requirements for program and design specifications, including software for safety-critical monitor and control; and definition of operational conditions and constraints.

c. Extensions and refinements of the PHA should coincide with the development of the design after the conceptual phase. A system generally consists of several discrete subsystems that should be individually analyzed (SSHA). The results of the SSHAs in turn feed into the SHA, which will integrate its subsystems and identify hazards that cross the subsystem interfaces. The number of systems and subsystems in a program is a function of the complexity of individual projects and will be determined by the program. In relatively simple programs, the SHA may also serve as the Integrated Hazard Analysis (IHA) if it also addresses risks. The hazard listing in the Safety Assessment Report (SAR) must be updated to indicate the closure of hazards and newly identified hazards. The SHA should be completed coincidentally with the Critical Design Review (CDR).

d. <u>Operating and Support Hazard Analysis (O&SHA)</u>. The O&SHA is performed primarily to identify and evaluate the hazards associated with the use of environment, personnel interface, procedures including automated command and control, and supporting facilities/equipment involved in the operation of a system/element. "Operation" for the purposes of this appendix may include, but is not limited to, activities such as testing, installation, maintenance, transportation, contingency operations, and others. This analysis considers the planned system configuration or state at each phase of activity, the facility interfaces, the planned environments (or their ranges), the supporting tools or other equipment specified for use, operational/task sequence, concurrent task effects and limitations, biotechnological factors, regulatory or specified personnel safety and health requirements, and the potential for unplanned events including hazards introduced by human errors (see paragraph g., Human Factor Engineering Analysis.) The O&SHA shall identify the safety requirements (i.e., constraints, limitations, conditions) to eliminate hazards or to reduce the associated risk to a level that is acceptable under either regulatory or specified criteria. An O&SHA is also used to validate design safety by verifying that the system will perform as expected if the operator correctly performs each step of approved procedures. The O&SHA should be updated when any system design or operational changes are included to ensure any needed hazard control changes.

e. Integrated Hazard Analysis (IHA). A complex program will require analysis of the widely divergent elements or system designs that must be assembled and operated together. The IHA ensures that hazards, along with their causes and controls, that cross element, system, or operational interfaces are identified, assessed, and resolved to an acceptable level. For purposes of the IHA, integration should be considered an element of a system. This analysis should start with an integrated PHA and progress in parallel with other system or element safety analyses. This analysis is broader in scope in that it looks at an entire program rather than a portion of it. The IHA process should act as a conduit to facilitate notification of affected systems or elements when a hazard, cause, or control crosses an interface.

f. Software Safety Analysis (SSA). A PHA identifies the safety-critical characteristics of a system. If the PHA identifies hazards that are functions assigned to an inhibit or software control of the system undergoing analysis, that software must undergo safety analysis. When a system software component has been identified as safety-critical, the software safety analysis process shall begin with the development of safety objectives. The software objectives shall be derived by examining the properties of each critical function and expressing them in terms of system responses and consequences. These objectives shall be unique to each safety-critical software component. Software safety analysis verifies that the software contains no errors or deficiencies that could contribute to risks to people or property. Software safety analysis consists of four phases: requirements analysis, design analysis, code analysis, and testing. The safety analysis effort shall begin with the requirements analysis phase of software development. This will ensure that all safety-critical requirements are specified and designed into the final software product. This approach to software safety analysis will provide optimum software safety with the least impact to the cost and schedule of the software development effort. The analysis techniques must be structured to allow for revisions and updates as the system matures.

g. Human Factors Engineering Analysis. The Program Manager should apply human factors engineering analysis for human error avoidance during the development and acquisition of NASA systems, equipment, software, and facilities to achieve the effective integration of the human element into system performance. A human error avoidance effort shall be provided to develop or improve the crew-equipment/software interface; to achieve required effectiveness of human performance during system operation and maintenance; to make economical use of personnel resources, skills, and training; and to minimize the possibility of human-induced error. Two-fault tolerance is required for all human errors that could result in a catastrophic hazard. The human error avoidance assessment shall be an integral part of the PHA, SHA, SSHA, and O&SHA as required. Human engineering principles shall be applied to the design to eliminate or mitigate potential hazards associated with the man-machine interface. Extensions or transformations of the results of system safety efforts for use in the human error avoidance task are not considered duplication.

5. The following tools and techniques shall be selected as appropriate to help identify the primary causes of an identified hazard:

a. Failure Modes and Effects Analysis (FMEA). The FMEA is usually performed by the assigned Reliability office to identify critical items in hardware. The FMEA should be used to assist safety personnel to perform hazard analyses and supplement, not replace, hazard analyses. Safety personnel can use the FMEA to help verify that all safety-critical hardware has been addressed in the hazard analyses. The FMEA in hardware systems is an important technique for evaluating the design and documenting the review process. All credible failure modes and their resultant effects at the component and system levels are identified and documented. The analysis follows a well-defined sequence of steps that encompasses (1) failure mode, (2) failure effects, (3) causes, (4) delectability, (5) corrective or preventative actions, and (6) rationale for acceptance.

b. Fault Tree Analysis (FTA). The FTA is a technique by which the system safety engineer can rigorously evaluate specific hazardous events. It is a type of logic tree that is developed by deductive logic from a top undesired event to all subevents that must occur to cause it. It is primarily used as a qualitative technique for studying hazardous events in systems, subsystems, components, or operations involving command paths. The FTA can be used to verify that the FMEA has identified all Critical Single Failure Points (CSFP's). It also can be used for quantitatively evaluating the probability of the top event and all subevent occurrences when sufficient and accurate data are available. Quantitative analyses shall be performed only when it is reasonably certain that the data for part/component failures and human errors for the operational environment exist. Cut sets shall be performed to establish fault tolerances.

c. Sneak Circuit Analysis (SCA). The SCA is a technique by which the system safety engineer can identify latent conditions (e.g. "electrical hydraulic, or other control systems) not caused by component failure that can inhibit desired functions or cause undesired functions to occur. A full-scale SCA may not be feasible depending on project constraints. Therefore, an SCA can be done on catastrophic hazards as identified by system-level FEMA or hazards analyses.

d. Event Tree Analysis (ETA). The ETA is a technique by which the system safety engineer can evaluate possible outcomes using a type of logic tree. It is an inductive logic method for identifying the various possible outcomes of a given initiating event.

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APPENDIX E: ACTIVITY AND FISSILE MATERIAL LIMITS BASIC A_1 /A_2 VALUES

301. Values of $\mathbf{A_1}$ and $\mathbf{A_2}$ for individual radionuclides, which are the basis for many activity limits elsewhere in these Regulations, are given in Table I.

DETERMINATION OF $\mathbf{A_1}$ AND $\mathbf{A_2}$

302. For individual radionuclides whose identities are known, but which are not listed in Table I, the determination of the values of $\mathbf{A_1}$ and $\mathbf{A_2}$ shall require **competent authority** approval or, for international transport, **multilateral approval.** Alternatively, the values of $\mathbf{A_1}$ and $\mathbf{A_2}$ in Table II may be used without obtaining **competent authority** approval.

303. In the calculations of $\mathbf{A_1}$ and $\mathbf{A_2}$ for a radionuclide not in Table I, a single radioactive decay chain in which the radionuclides are present in their naturally occurring proportions and in which no daughter nuclide has a half-life either longer than 10 days or longer than that of the parent nuclide shall be considered as a single radionuclide, and the activity to be taken into account and the $\mathbf{A_1}$ or $\mathbf{A_2}$ value to be applied shall be those corresponding to the parent nuclide of that chain. In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than 10 days or greater than that of the parent nuclide, the parent and such daughter nuclides shall be considered as mixtures of different nuclides.

304. For mixtures of radionuclides whose identities and respective activities are known the following conditions shall apply:

(a) For **special form radioactive material:**

$$\sum_i \frac{B(i)}{A_1(i)} \text{ less than or equal to } 1$$

(b) For other forms of **radioactive material:**

$$\sum_i \frac{B(i)}{A_2(i)} \text{ less than or equal to } 1$$

where B(i) is the activity of radionuclide i and $\mathbf{A_1}$(i) and $\mathbf{A_2}$(i) are the $\mathbf{A_1}$ and $\mathbf{A_2}$ values for radionuclide i, respectively.

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{225}Ac (b)*	Actinium (89)	0.6	10	1×10^{-2}	2×10^{-1}
^{227}Ac		40	1000	2×10^{-5}	5×10^{-4}
^{228}Ac		0.6	10	0.4	10
^{105}Ag	Silver (47)	2	50	2	50
$^{108}Ag^m$		0.6	10	0.6	10
$^{110}Ag^m$		0.4	10	0.4	10
^{111}Ag		0.6	10	0.5	10
^{26}Al	Aluminum (13)	0.4	10	0.4	10
^{241}Am	Americium (95)	2	50	2×10^{-4}	5×10^{-3}
$^{242}Am^m$		2	50	2×10^{-4}	5×10^{-3}
^{243}Am		2	50	2×10^{-4}	5×10^{-3}
^{37}Ar	Argon (18)	40	1000	40	1000
^{39}Ar		20	500	20	500
^{41}Ar		0.6	10	0.6	10
^{42}Ar (b)		0.2	5	0.2	5
^{72}As	Arsenic(33)	0.2	5	0.2	5
^{73}As		40	1000	40	1000
^{74}As		1	20	0.5	10
^{76}As		0.2	5	0.2	5
^{77}As		20	500	0.5	10
^{211}At	Astatine (85)	30	800	2	50

* Note: (b) indicates a footnote at the end of Table I: this form is used to avoid confusion with the superscript m.

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{193}Au	Gold (79)	6	100	6	100
^{194}Au		1	20	1	20
^{195}Au		10	200	10	200
^{196}Au		2	50	2	50
^{198}Au		3	80	0.5	10
^{199}Au		10	200	0.9	20
^{131}Ba	Barium (56)	2	50	2	50
$^{133}Ba^m$		10	200	0.9	20
^{133}Ba		3	80	3	80
^{140}Ba (b)		0.4	10	0.4	10
^{7}Be	Beryllium (4)	20	500	20	500
^{10}Be		20	500	0.5	10
^{205}Bi	Bismuth (83)	0.6	10	0.6	10
^{206}Bi		0.3	8	0.3	8
^{207}Bi		0.7	10	0.7	10
$^{210}Bi^m$ (b)		0.3	8	3×10^{-2}	8×10^{-1}
^{210}Bi		0.6	10	0.5	10
^{212}Bi (b)		0.3	8	0.3	8
^{247}Bk	Berkelium (97)	2	50	2×10^{-4}	5×10^{-3}
^{249}Bk		40	1000	8×10^{-2}	2
^{76}Br	Bromine (35)	0.3	8	0.3	8
^{77}Br		3	80	3	80
^{82}Br		0.4	10	0.4	10
^{11}C	Carbon (6)	1	20	0.5	10
^{14}C		40	1000	2	50
^{41}Ca	Calcium (20)	40	1000	40	1000
^{45}Ca		40	1000	0.9	20
^{47}Ca		0.9	20	0.5	10
^{109}Cd	Cadmium (48)	40	1000	1	20
$^{113}Cd^m$		20	500	9×10^{-2}	2
$^{115}Cd^m$		0.3	8	0.3	8
^{115}Cd		4	100	0.5	10
^{139}Ce	Cerium (58)	6	100	6	100
^{141}Ce		10	200	0.5	10
^{143}Ce		0.6	10	0.5	10
^{144}Ce (b)		0.2	5	0.2	5

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{248}Cf	Californium (98)	30	800	3×10^{-3}	8×10^{-2}
^{249}Cf		2	50	2×10^{-4}	5×10^{-3}
^{250}Cf		5	100	5×10^{-4}	1×10^{-2}
^{251}Cf		2	50	2×10^{-4}	5×10^{-3}
^{252}Cf		0.1	2	1×10^{-3}	2×10^{-2}
^{253}Cf		40	1000	6×10^{-2}	1
^{254}Cf		3×10^{-3}	8×10^{-2}	6×10^{-4}	1×10^{-2}
^{36}Cl	Chlorine (17)	20	500	0.5	10
^{38}Cl		0.2	5	0.2	5
^{240}Cm	Curium (96)	40	1000	2×10^{-2}	5×10^{-1}
^{241}Cm		2	50	0.9	20
^{242}Cm		40	1000	1×10^{-2}	2×10^{-1}
^{243}Cm		3	80	3×10^{-4}	8×10^{-3}
^{244}Cm		4	100	4×10^{-4}	1×10^{-2}
^{245}Cm		2	50	2×10^{-4}	5×10^{-3}
^{246}Cm		2	50	2×10^{-4}	5×10^{-3}
^{247}Cm		2	50	2×10^{-4}	5×10^{-3}
^{248}Cm		4×10^{-2}	1	5×10^{-5}	1×10^{-3}
^{55}Co	Cobalt (27)	0.5	10	0.5	10
^{56}Co		0.3	8	0.3	8
^{57}Co		8	200	8	200
$^{58}Co^{m}$		40	1000	40	1000
^{58}Co		1	20	1	20
^{60}Co		0.4	10	0.4	10

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{51}Cr	Chromium (24)	30	800	30	800
^{129}Cs	Caesium (55)	4	100	4	100
^{131}Cs		40	1000	40	1000
^{132}Cs		1	20	1	20
$^{134}Cs^{m}$		40	1000	9	200
^{134}Cs		0.6	10	0.5	10
^{135}Cs		40	1000	0.9	20
^{136}Cs		0.5	10	0.5	10
^{137}Cs (b)		2	50	0.5	10
^{64}Cu	Copper (29)	5	100	0.9	20
^{67}Cu		9	200	0.9	20
^{159}Dy	Dysprosium (66)	20	500	20	500
^{165}Dy		0.6	10	0.5	10
^{166}Dy (b)		0.3	8	0.3	8
^{169}Er	Erbium (68)	40	1000	0.9	20
^{171}Er		0.6	10	0.5	10
^{147}Eu	Europium (63)	2	50	2	50
^{148}Eu		0.5	10	0.5	10
^{149}Eu		20	500	20	500
^{150}Eu		0.7	10	0.7	10
$^{152}Eu^{m}$		0.6	10	0.5	10
^{153}Eu		0.9	20	0.9	20
^{154}Eu		0.8	20	0.5	10
^{155}Eu		20	500	2	50
^{156}Eu		0.6	10	0.5	10
^{18}F	Fluorine (9)	1	20	0.5	10
^{52}Fe (b)	Iron (26)	0.2	5	0.2	5
^{55}Fe		40	1000	40	1000
^{59}Fe		0.8	20	0.8	20
^{60}Fe		40	1000	0.2	5

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{67}Ga	Gallium (31)	6	100	6	100
^{68}Ga		0.3	8	0.3	8
^{72}Ga		0.4	10	0.4	10
^{146}Gd (b)	Gadolinium (64)	0.4	10	0.4	10
^{148}Gd		3	80	3×10^{-4}	8×10^{-3}
^{153}Gd		10	200	5	100
^{159}Gd		4	100	0.5	10
^{68}Ge (b)	Germanium (32)	0.3	8	0.3	8
^{71}Ge		40	1000	40	1000
^{77}Ge		0.3	8	0.3	8
^{172}Hf (b)	Hafnium (72)	0.5	10	0.3	8
^{175}Hf		3	80	3	80
^{18l}Hf		2	50	0.9	20
^{182}Hf		4	100	3×10^{-2}	8×10^{-1}
^{194}Hg (b)	Mercury (80)	1	20	1	20
^{195}Hg^m		5	100	5	100
^{197}Hg^m		10	200	0.9	20
^{197}Hg		10	200	10	200
^{203}Hg		4	100	0.9	20
^{163}Ho	Holmium (67)	40	1000	40	1000
^{166}Ho^m		0.6	10	0.3	8
^{166}Ho		0.3	8	0.3	8
^{123}I	Iodine (53)	6	100	6	100
^{124}I		0.9	20	0.9	20
^{125}I		20	500	2	50
^{126}I		2	50	0.9	20
^{129}I		Unlimited		Unlimited	
^{131}I		3	80	0.5	10
^{132}I		0.4	10	0.4	10
^{133}I		0.6	10	0.5	10
^{134}I		0 3	8	0.3	8
^{135}I		0.6	10	0.5	10

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{111}In	Indium (49)	2	50	2	50
$^{113}In^{m}$		4	100	4	100
$^{114}In^{m}$ (b)		0.3	8	0 3	8
$^{115}In^{m}$		6	100	0.9	20
^{189}Ir	Iridium (77)	10	200	10	200
^{190}Ir		0.7	10	0.7	10
^{192}Ir		1	20	0.5	10
$^{193}Ir^{m}$		10	200	10	200
^{194}Ir		0.2	5	0.2	5
^{40}K	Potassium (19)	0.6	10	0.6	10
^{42}K		0.2	5	0.2	5
^{43}K		1	20	0.5	10
^{81}Kr	Krypton (36)	40	1000	40	1000
$^{85}Kr^{m}$		6	100	6	100
^{85}Kr		20	500	10	200
^{87}Kr		0.2	5	0.2	5
^{137}La	Lanthanum (57)	40	1000	2	50
^{140}La		0.4	10	0.4	10
LSA	Low specific activity material (see para. 131 of Parent Document)				
^{172}Lu	Lutetium (71)	0.5	10	0.5	10
^{173}Lu		8	200	8	200
$^{174}Lu^{m}$		20	500	8	200
^{174}Lu		8	200	4	100
^{177}Lu		30	800	0.9	20
MFP	For mixed fission products, use formula for mixtures or Table II				
^{28}Mg (b)	Magnesium (12)	0.2	5	0.2	5
^{52}Mn	Manganese (25)	0.3	8	0.3	8
^{53}Mn		Unlimited		Unlimited	
^{54}Mn		1	20	1	20
^{56}Mn		0.2	5	0.2	5

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{93}Mo	Molybdenum (42)	40	1000	7	100
^{99}Mo		0.6	10	0.5	10
^{13}N	Nitrogen (7)	0.6	10	0.5	10
^{22}Na	Sodium (11)	0.5	10	0.5	10
^{24}Na		0.2	5	0.2	5
^{92}Nb^m	Niobium (41)	0.7	10	0.7	10
^{93}Nb^m		40	1000	6	100
^{94}Nb		0.6	10	0.6	10
^{95}Nb		1	20	1	20
^{97}Nb		0.6	10	0.5	10
^{147}Nd	Neodymium (60)	4	100	0.5	10
^{149}Nd		0.6	10	0.5	10
^{59}Ni	Nickel (28)	40	1000	40	1000
^{63}Ni		40	1000	30	800
^{65}Ni		0.3	8	0.3	8
^{235}Np	Neptunium (93)	40	1000	40	1000
^{236}Np		7	100	1×10^{-3}	2×10^{-2}
^{237}Np		2	50	2×10^{-4}	5×10^{-3}
^{239}Np		6	100	0.5	10
^{185}Os	Osmium (76)	1	20	1	20
^{191}Os^m		40	1000	40	1000
^{191}Os		10	200	0.9	20
^{193}Os		0.6	10	0.5	10
^{194}Os (b)		0.2	5	0.2	5
^{32}P	Phosphorus (15)	0.3	8	0.3	8
^{33}P		40	1000	0.9	20
^{230}Pa	Protactinium (91)	2	50	0.1	2
^{231}Pa		0.6	10	6×10^{-5}	1×10^{-3}
^{233}Pa		5	100	0.9	20

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{201}Pb	Lead (82)	1	20	1	20
^{202}Pb		40	1000	2	50
^{203}Pb		3	80	3	80
^{205}Pb		Unlimited		Unlimited	
^{210}Pb (b)		0.6	10	9×10^{-3}	2×10^{-1}
^{212}Pb (b)		0.3	8	0.3	8
^{103}Pd	Palladium (46)	40	1000	40	1000
^{107}Pd		Unlimited		Unlimited	
^{109}Pd		0.6	10	0.5	10
^{143}Pm	Promethium (61)	3	80	3	80
^{144}Pm		0.6	10	0.6	10
^{145}Pm		30	800	7	100
^{147}Pm		40	1000	0.9	20
^{148}Pm^{m}		0.5	10	0.5	10
^{149}Pm		0.6	10	0.5	10
^{151}Pm		3	80	0.5	10
^{208}Po	Polonium (84)	40	1000	2×10^{-2}	5×10^{-1}
^{209}Po		40	1000	2×10^{-2}	5×10^{-1}
^{210}Po		40	1000	2×10^{-2}	5×10^{-1}
^{142}Pr	Praseodymium (59)	0.2	5	0.2	5
^{143}Pr		4	100	0.5	10
^{188}Pt (b)	Platinum (78)	0.6	10	0.6	10
^{191}Pt		3	80	3	80
^{193}Pt^{m}		40	1000	9	200
^{193}Pt		40	1000	40	1000
^{195}Pt^{m}		10	200	2	50
^{197}Pt^{m}		10	200	0.9	20
^{197}Pt		20	500	0.5	10

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{236}Pu	Plutonium (94)	7	100	7×10^{-4}	1×10^{-2}
^{237}Pu		20	500	20	500
^{238}Pu		2	50	2×10^{-4}	5×10^{-3}
^{239}Pu		2	50	2×10^{-4}	5×10^{-3}
^{240}Pu		2	50	2×10^{-4}	5×10^{-3}
^{241}Pu		40	1000	1×10^{-2}	2×10^{-1}
^{242}Pu		2	50	2×10^{-4}	5×10^{-3}
^{244}Pu (b)		0.3	8	2×10^{-4}	5×10^{-3}
^{223}Ra (b)	Radium (88)	0.6	10	3×10^{-2}	8×10^{-1}
^{224}Ra (b)		0.3	8	6×10^{-2}	1
^{225}Ra (b)		0.6	10	2×10^{-2}	5×10^{-1}
^{226}Ra (b)		0.3	8	2×10^{-2}	5×10^{-1}
^{228}Ra (b)		0.6	10	4×10^{-2}	1
^{81}Rb	Rubidium (37)	2	50	0.9	20
^{83}Rb		2	50	2	50
^{84}Rb		1	20	0.9	20
^{86}Rb		0.3	8	0.3	8
^{87}Rb		Unlimited		Unlimited	
Rb (natural)		Unlimited		Unlimited	
^{183}Re	Rhenium (75)	5	100	5	100
$^{184}Re^m$		3	80	3	80
^{184}Re		1	20	1	20
^{186}Re		4	100	0.5	10
^{187}Re		Unlimited		Unlimited	
^{188}Re		0.2	5	0.2	5
^{189}Re		4	100	0.5	10
Re (natural)		Unlimited		Unlimited	
^{99}Rh	Rhodium (45)	2	50	2	50
^{101}Rh		4	100	4	100
$^{102}Rh^m$		2	50	0.9	20
^{102}Rh		0.5	10	0.5	10
$^{103}Rh^m$		40	1000	40	1000
^{105}Rh		10	200	0.9	20
^{222}Rn (b)	Radon (86)	0.2	5	4×10^{-3}	1×10^{-1}

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{97}Ru	Ruthenium (44)	4	100	4	100
^{103}Ru		2	50	0.9	20
^{105}Ru		0.6	10	0.5	10
^{106}Ru (b)		0.2	5	0.2	5
^{35}S	Sulfur (16)	40	1000	2	50
^{122}Sb	Antimony (51)	0.3	8	0.3	8
^{124}Sb		0.6	10	0.5	10
^{125}Sb		2	50	0.9	20
^{126}Sb		0.4	10	0.4	10
^{44}Sc	Scandium (21)	0.5	10	0.5	10
^{46}Sc		0.5	10	0.5	10
^{47}Sc		9	200	0.9	20
^{48}Sc		0.3	8	0.3	8
SCO	Surface contaminated objects (see para. 144 of Parent Document)				
^{75}Se	Selenium (34)	3	80	3	80
^{79}Se		40	1000	2	50
^{31}Si	Silicon (14)	0.6	10	0.5	10
^{32}Si		40	1000	0.2	5
^{145}Sm	Samarium (62)	20	500	20	500
^{147}Sm		Unlimited		Unlimited	
^{151}Sm		40	1000	4	100
^{153}Sm		4	100	0.5	10
^{113}Sn (b)	Tin (50)	4	100	4	100
^{117}Sn^{m}		6	100	2	50
^{119}Sn^{m}		40	1000	40	1000
^{121}Sn^{m}		40	1000	0.9	20
^{123}Sn		0.6	10	0.5	10
^{125}Sn		0.2	5	0.2	5
^{126}Sn (b)		0.3	8	0.3	8

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{82}Sr (b)	Strontium (38)	0.2	5	0.2	5
^{85}Sr^{m}		5	100	5	100
^{85}Sr		2	50	2	50
^{87}Sr^{m}		3	80	3	80
^{89}Sr		0.6	10	0.5	10
^{90}Sr (b)		0.2	5	0.1	2
^{91}Sr		0.3	8	0.3	8
^{92}Sr (b)		0.8	5	0.5	10
T (all forms)	Tritium (1)	40	1000	40	1000
^{178}Ta	Tantalum (73)	1	20	1	20
^{179}Ta		30	800	30	800
^{182}Ta		0.8	20	0.5	10
^{157}Tb	Terbium (65)	40	1000	10	200
^{158}Tb		1	20	0.7	10
^{160}Tb		0.9	20	0.5	10
^{95}Tc^{m}	Technetium (43)	2	50	2	50
^{96}Tc^{m} (b)		0.4	10	0.4	10
^{96}Tc		0 4	10	0.4	10
^{97}Tc^{m}		40	1000	40	1000
^{97}Tc		Unlimited		Unlimited	
^{98}Tc		0.7	10	0.7	10
^{99}Tc^{m}		8	200	8	200
^{99}Tc		40	1000	0.9	20
^{118}Te (b)	Tellurium (52)	0.2	5	0.2	5
^{121}Te^{m}		5	100	5	100
^{121}Te		2	50	2	50
^{123}Te^{m}		7	100	7	100
^{125}Te^{m}		30	800	9	200
^{127}Te^{m} (b)		20	500	0.5	10
^{127}Te		20	500	0.5	10
^{129}Te^{m} (b)		0.6	10	0.5	10
^{129}Te		0.6	10	0.5	10
^{131}Te^{m}		0.7	10	0.5	10
^{132}Te (b)		0.4	10	0.4	10

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{227}Th	Thorium (90)	9	200	1×10^{-2}	2×10^{-1}
^{228}Th (b)		0.3	8	4×10^{-4}	1×10^{-2}
^{229}Th		0.3	8	3×10^{-5}	8×10^{-4}
^{230}Th		2	50	2×10^{-4}	5×10^{-3}
^{231}Th		40	1000	0.9	20
^{232}Th		Unlimited		Unlimited	
^{234}Th (b)		0.2	5	0.2	5
Th (natural)		Unlimited		Unlimited	
^{44}Ti (b)	Titanium (22)	0.5	10	0.2	5
^{200}Ti	Thallium (81)	0.8	20	0.8	20
^{201}Ti		10	200	10	200
^{202}Ti		2	50	2	50
^{204}Ti		4	100	0.5	10
^{167}Tm	Thulium (69)	7	100	7	100
^{168}Tm		0.8	20	0.8	20
^{170}Tm		4	100	0.5	10
^{171}Tm		40	1000	10	200
^{230}U	Uranium (92)	40	1000	1×10^{-2}	2×10^{-1}
^{232}U		3	80	3×10^{-4}	8×10^{-3}
^{233}U		10	200	1×10^{-3}	2×10^{-2}
^{234}U		10	200	1×10^{-3}	2×10^{-2}
^{235}U		Unlimited [c]		Unlimited [c]	
^{236}U		10	200	1×10^{-3}	2×10^{-2}
^{238}U		Unlimited		Unlimited	
U (natural)		Unlimited		Unlimited [d]	
U (enriched 5% or less)		Unlimited [c]		Unlimited [c,d]	
U (enriched more than 5%)		10	200	1×10^{-3} [d]	2×10^{-2}
U (depleted)		Unlimited		Unlimited [d]	
^{48}V	Vanadium (23)	0.3	8	0.3	8
^{49}V		40	1000	40	1000

TABLE I. A_1 AND A_2 VALUES FOR RADIONUCLIDES (Continued)

Symbol of radionuclide	Element and atomic number	A_1 (TBq)	A_1 (Ci) (approx. [a])	A_2 (TBq)	A_2 (Ci) (approx. [a])
^{178}W (b)	Tungsten (74)	1	20	1	20
^{181}W		30	800	30	800
^{185}W		40	1000	0.9	20
^{187}W		2	50	0.5	10
^{188}W (b)		0.2	5	0.2	5
^{122}Xe (b)	Xenon (54)	0.2	5	0.2	5
^{123}Xe		0.2	5	0.2	5
^{127}Xe		4	100	4	100
$^{131}Xe^m$		40	1000	40	1000
^{133}Xe		20	500	20	500
^{135}Xe		4	100	4	100
^{87}Y	Yttrium (39)	2	50	2	50
^{88}Y		0.4	10	0.4	10
^{90}Y		0.2	5	0.2	5
$^{91}Y^m$		2	50	2	50
^{91}Y		0.3	8	0.3	8
^{92}Y		0.2	5	0.2	5
^{93}Y		0.2	5	0.2	5
^{l69}Yb	Ytterbium (70)	3	80	3	80
^{175}Yb		30	800	0.9	20
^{65}Zn	Zinc (30)	2	50	2	50
$^{69}Zn^m$ (b)		2	50	0.5	10
^{69}Zn		4	100	0.5	10
^{88}Zr	Zirconium (40)	3	80	3	80
^{93}Zr		40	1000	0.2	5
^{95}Zr		1	20	0.9	20
^{97}Zr		0.3	8	0.3	8

[a] The curie values quoted are obtained by rounding down from the TBq figure after conversion to Ci.
This ensures that the magnitude of $\mathbf{A_l}$ or $\mathbf{A_2}$ in Ci is always less than that in Tbq.

[b] $\mathbf{A_l}$ and/or $\mathbf{A_2}$ value limited by daughter product decay.

[c] $\mathbf{A_l}$ and $\mathbf{A_2}$ are unlimited for radiation control purposes only. For nuclear criticality safety this material is subject to the control placed on **fissile material.**

[d] These values do not apply to reprocessed uranium.

Alternatively, an A_2 value for mixtures may be determined as follows:

$$A_2 \text{for mixture} = \frac{1}{\displaystyle E_i \frac{f\,(i)}{A_2(i)}}$$

where is f (i) is the fraction of activity of nuclide i in the mixture and $\mathbf{A_2}$ (i) is the appropriate $\mathbf{A_2}$ value for nuclide i.

305. When the identity of each radionuclide is known but the individual activities of some of theradionuclides are not known, the radionuclides may be grouped and the lowest $\mathbf{A_1}$ or $\mathbf{A_2}$ value, as appropriate, for the radionuclides in each group may be used in applying the formulas in para. 304. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest $\mathbf{A_1}$ or $\mathbf{A_2}$ values for the alpha emitters or beta/gamma emitters, respectively.

306. For individual radionuclides or for mixtures of radionuclides for which relevant data are not available, the values shown in Table II shall be used.

TABLE II. GENERAL VALUES FOR A_1 AND A_2

Contents	A_1		A_2	
	TBq	(Ci)[a]	TBq	(Ci)[a]
Only beta or gamma emitting nuclides are known to be present	0.2	(5)	0.02	(0.5)
Alpha emitting nuclides are known to be present or no relevant data are available	0.1	(2)	2×10^{-5}	(5×10^{-4})

[a] The curie values quoted in parentheses are approximate values and are not higher than the TBq values.